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REMOTE STORAGE

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Vacuum Brake, Eames' Automatic Duplex CLVII, CLIX, CLX, CLXVII
General Engine Arrangement CLV
,, Carriage Arrangement CLVI
Valve Gear, Locomotive :—
Allen's Straight Link ... ... Fig. 5 CXLIV
Bury's ... ... ,, 2 CXLIV
Carmichael's ... ... ,, 3 CXLIV
Gray's ... ... ,, 9 CXLIV
Hawthorn's ... ... ,, 5 & 8 CXLIV
Howe's ... ... ,, 12 CXLIV
Melling's... ... ... ,, 7 CXLIV
Walschaert's ... ... ,, 14 CXLIV

Way, Bergeron's Permanent ... ... CLXI, CLXII
,, Permanent Improvements in CLII
Webb's Facing Point Lock CXXXIV
,, 3 Cylinder Compound Locomotive ... ... CXL, CLXX
,, Interlocking Apparatus CLIII
White's Fog Signals CLXVI

THE CANONBURY ACCIDENT.

WE are not often induced to anticipate, by comments of our own, the carefully conducted enquiries and able reports of the Board of Trade Inspectors. We depart from our usual course with regard to the deplorable accident at Canonbury Junction, because it affords a conspicuous example of serious defects in the working of the block system—a system on which nearly all our railway companies rely for the safety of the traffic on their lines. Those defects are well known to railway engineers. Numerous accidents have proved that the signalling arrangements, although greatly improved within the last ten years, are, nevertheless, liable to failure, and that at any moment a poor overworked signalman may commit an error which will lead to the most appalling disaster So thoroughly do railway engineers understand the extent and nature of the risk to which the public are exposed by the present operation of the block system that when Her Majesty the Queen travels on railways in Great Britain it is usual to allow a clear twenty minutes to elapse between the starting of the royal train and other trains on the same line. There is a missing link in the precautionary arrangements which now and again becomes disastrously manifest, and awakens us to the urgent need of closer attention to the subject of signalling apparatus. This missing link is the absence of an efficient check on the signalman who from ignorance, incapacity, or inattention may commit a fatal blunder. Is it possible to introduce any improvements which will diminish the risk of such mistakes? We will not enter into the question of cost; that is always the unfortunate argument for delay. Mr. Moon, the Chairman of the London and North-Western Railway Company, when asked to aid in the encouragement of scientific investigations for improvements in railway engineering, curtly replied: "We are very simple people, and all we care about is our dividend.'" This is not the spirit in which the majority of railway companies regard the urgent need for improved safety appliances. The administrative departments of our great railways are conducted by men of exceptional ability, and they fully recognize the importance of keeping pace with the increasing pressure of traffic by testing and adopting meritorious inventions. The delay really arises in the slow process of experiment, and a certain fear of adopting one system at great expenditure which may soon afterwards be surplanted by something better. Remedies for the defects of the block system have been before the public for some time past, and have been in very successful operation on the Metropolitan District Railway.

Major Marindin in reporting on a collision which occurred on the 8th October, 1880, at Penilee, between Cardonald and Paisley, on the Glasgow and Paisley Joint Railway, concludes with the following remarks:—"This accident is one of a class which shows how the system of block working and interlocking of signals, now in general use, is liable to break down at times from mistakes arising from human fallibility, and it is needless, in the face of such a catastrophe, to waste words in arguing how great must be the value of any invention which will prevent such mistakes from occurring, and will establish an absolute mechanical block which cannot fail from the error of one man. Such an invention appears to exist in the systems of electrically interlocked signals and block instruments, one of which is in use on the London, Chatham, and Dover Railway and the Metropolitan District Railway, where it is stated to be working successfully. If such a system had been in use on the Glasgow and Paisley Joint Line, and had been properly carried out at Penilee signal cabin, this collision could not have been brought about by the mistake of the signalman, for it would have been quite impossible for him to have placed the goods train upon the down main line after he had given 'line clear' for the passenger train, while if he had first placed the goods train

on the down main line, he could not have given 'line clear' or lowered his signals for the passenger train, until he had shunted the goods train clear of this line. I trust that when this system becomes more generally known, it will be tried upon other lines, and will, if found satisfactory, be universally adopted."

The system to which Major Marindin alluded was fully described at page 50, Vol. I., of *The Railway Engineer.* It is the invention of Mr. Sykes, an officer of the London, Chatham and Dover Railway, and the following advantages are claimed for it :—

Greatly enhanced safety to life and property in travelling, nothing being left to the memory of the men who work the signals.

The absolute impossibility for more than one train to be in any one section of the line at the same time, which frequently occurs with the block system, but cannot happen with Sykes' patent, risk of collision being thereby reduced to a minimum.

Simplicity of construction, extreme facility of working and of comprehension by the men, also its ready adaptability to the ordinary signal and point levers at present in use.

Economy in original cost, and a considerable annual saving in maintenance and working.

Distance no object, the placing of signals being a mere question of traffic and detail.

Our illustration, Plate CXXIXA, demonstrates very clearly the impossibility of the accident at Canonbury Junction had such an invention been in use.

It will be seen by reference to the diagrams that Hovey's arm galvanometer at C standing at danger, which is a block instrument in itself, and the upper portion of the indicator, showing blocked to D, and the fact of the lever working the out-door signal being "locked," *i.e.*, immovable, Hovey could not possibly have construed the six or seven beats on the bell into a "permissive block," because by the extreme simplicity of Sykes' invention, Hovey would have known that "train 1" had not passed out of the section ahead, so it would not have been necessary to "flag" train 2 past the out-door signal standing at danger. Why? Because there were three (3) reasons he should not, viz :—

First.—The arm galvanometer showed an obstruction on the line between C and D 1
Second.—The indicator showed blocked to D 2
Third.—Hovey's lever working the out-door signal was locked at "Danger" and immovable 3

Further, "Hovey could not use his plunger to allow B to send "train 3" on towards C, because his lever had not been released by D, it follows that "train 4" standing at A, could not move for similar reason, being controlled in same manner as train 3.

Unless, therefore, the *three* men respectively stationed at A, B, and C, "flagged trains" 2, 3, and 4 against or past three out-door signals at danger, against three arm galvanometers, and against three block indicators *which lock the levers*—nine instruments in all, including the three locked levers, *a total of twelve safeguards, the Canonbury disaster could not have occurred or twenty-four if all on a straight line.*

New Railway Bridge.—The London and South-Western Railway are about to construct a new bridge over Garrett-lane, Wandsworth. At present the plans are awaiting the decision of the Wandsworth District Board of Works and the Metropolitan Board.

The International Railway Materials Exhibition at Berlin.—The Association of German Steel and Iron Industries recently met at Berlin, and pronounced against the project of an international exhibition of railway materials at Berlin, as the benefits to be derived from such an exhibition by the iron trade would be very trivial as com- with the costs of organization.

Locomotives on the Eastern Bengal.—The average number of locomotives undergoing repairs and renewals at any one time on the Eastern Bengal Railway during the half-year ending June 30, 1881, was 19.42 per cent. of the whole stock, or about one-fifth.

Baldwin Locomotives.—At the Baldwin Locomotive Works, Philadelphia, 555 locomotives will be built this year. They are intended for lines in the United States, in Cuba, Mexico, Brazil, Peru, and Chili. There are nearly 3,000 men employed at the shops.

Steel Rails in Germany.—The German railway companies make no distinction between ordinary rails of Bessemer steel and those made by the Gilchrist process. The Hoerde Works and the Rhenish Steel Company are turning out over 30,000 tons annually of rails made by this process.

ELEVATED RAILWAYS OF NEW YORK.

THE great success of the Elevated Railroads of New York ought to serve as an argument in favour of the adoption of this class of railway in our own metropolis. Such a line would be a great boon to business men in some of our suburbs, in enabling them to reach their destinations quickly, as the lines at present in operation will no doubt in the course of a few years be quite inadequate to meet the great demands put upon them during certain hours of the morning and evening. In fact, it is a question if some are not already in such a position. It is very probable that a line on this system of construction would at first be looked upon with little favour by the public, who no doubt could bring many reasonable objections to it, still with our continually increasing traffic they would see that this or some other form of railway, different to those already constructed, must, before long, be adopted as a real necessity. The following description of the Elevated Railroad is taken from the *Revue Générale des Chemins de Fer*, and gives a good idea of the extent and nature of the operations necessary for the undertaking.

The Elevated Railroads of New York were constructed by two companies, the New York Elevated Company and the Metropolitan Company, which are now united, and form the Manhattan Company, who work all the lines.

A length of three miles was opened in 1868 and worked by means of wire ropes, which were substituted in 1871 by locomotives. At the first opening, traffic was very small, the public would not trust themselves on this shaky road, and it was necessary to reconstruct the entire line more solidly.

In 1876 the Metropolitan Company commenced the construction of another line, but a law suit stopped the works from the month of April, 1876, to that of November, 1877. The company gained their cause before the High Court of Appeal, and the works were recommenced in 1878, and vigorously proceeded with. The contract for the iron work had been divided into three lots, and given to Messrs. Clark, Reeves & Co., of the Phœnixvill Foundry (Pensylvania), and to the Heystone and Edgemor Companies. In June, 1878, train service commenced on five miles of this line, with more success than the original. The trains started every three minutes from 5 o'clock in the morning till midnight.

The carriages were very comfortable and well constructed. All trains were furnished with continuous brakes; the points and signals were worked on Saxby & Farmer's interlocking system. The section of the Metropolitan Company contained four curves of a radius of ninety feet, upon which took place, without accidents or excessive wear of the rails or tyres, a circulation of 839 trains per day. The gauge of the road is four feet eight and a-half inches.

In November, 1877, the Metropolitan Company had confided to Messrs. Clark, Reeves & Co., the work of extending the line to a length of about four miles from Street 83, to the river Harlem, and the construction of a section of seven miles of a third line. For the execution of these works there were required 44,700 tons of iron, comprising 971 miles of angle iron, 314 miles of bar iron, and two acres of plate iron, twenty miles of columns of the Phœnix type. There were used 5,500,000 rivets, and the work necessitated the drilling of 22,000,000 holes. The contract specified that all the work must be finished by the end of nine months at the 1st of September, 1879; so that really, deducting the inevitable loss of time occasioned by the preparation for the works, the time spent in transport and mounting the parts in their places, the execution of this contract only left 190 days' work for the rolling-mills, and 200 days' work for the workmen, which was equivalent to furnishing each week 1,340 tons of finished ironwork to rolling each day. Five miles of angle iron and one and a-half miles of bar iron, also to make every twenty-four hours, 520 feet of Phœnix columns, to set 27,500 rivets, and punch 110,000 holes. The work was pursued day and night without interruption by the use of the electric light. On September 1st, 1879, one section was finished, and another would also have been finished had not the Company granted a delay for particular reasons, in virtue of which the last three miles were not finished till the spring of 1880.

In the Isle of Manhattan the line crossed a valley by means of a viaduct 4,000 feet long, forty-five feet mean height, and of which the maximum elevation above the pavement of the streets attained to sixty feet. This part of the work is represented by Figs. 3 and 4, Plate CXXXV.

The line along the second avenue has a mean height of twenty feet; it sometimes attains to fifty feet. The line is constructed so as to receive four roads, but only two are actually laid, and when the other two are required it will become necessary to increase the distance between the outside beams a little.

The establishment of the foundations of four miles of the first line finished, viz., from 83 Street to the River Harlem presented some serious and unforeseen difficulties, owing to the bad nature of the ground.

The foundations of the piles were always beneath the gas, water, and drain pipes. In the Isle of Manhattan the soil is very irregular and rocky. It often became necessary to dig to a depth of thirty feet in the sand for a foundation, while sometimes the solid rock had to be bored to a depth of ten and twelve feet in order to take the foundations below the level of the drains. The following

figures give some idea of the extent of the underground work which was necessary for the construction of the four miles of the line extending from 83 Street to the River Harlem; it employed 11,500,000 bricks, 32,000 barrels of cement, 1,815 piles, 9000 cubic yards of concrete; also 63,000 yards of earth, were excavated, 25,800 yards of loose rock, and 6,400 yards of solid rock were raised.

Types of Viaducts.—Figs. 1 and 2, Plate CXXXV. represent the type of viaduct adopted for the second avenue.

The columns, at a distance of 43 ft. from centre to to centre longitudinally, are maintained by ribs in cast-iron sockets, the base of which forms the foundation plate resting on a mass of brickwork supported on a flagstone, which itself rests on a course of concrete the thickness of which varys with the nature of the soil. Four holding-down bolts of 2¼ in. diameter hold the base of each socket of the columns to the flagstone beneath.

Also, as will be seen from Figs. 1 and 2, the columns are connected longitudinally in pairs by the lattice beams, a b, and also transversely by the beams c d; the four columns are braced diagonally in both directions by the rods, t t. The same figures show the method of constructing the top of the viaduct; the longitudinal beams are joined only at the top to the transverse beams by the angle irons, f f, in or to facilitate dismounting or extending the work.

Figs. 3 and 4 show the mode of construction employed for the line along the eighth avenue, where the height of the viaduct varied from 45 ft. to 60 ft., and where the foundations were very difficult to form. The transverse lattice beams of the preceding form of construction are replaced by the forms represented at Fig. 4, composed of a plain beam connected with the tops of the columns by the jointed system of brace-work shown, the small uprights p, p', p'' being of the same type as the Phœnix columns.

The longitudinal beams are of the same type as those of the viaduct of the second avenue; here only three lines are laid. These beams are connected in pairs by lattice work (Fig. 3), and united to each other at regular intervals of their length by angle irons.

In the case of a part of the viaduct of the second avenue, of which the mean height is only 16 ft., each column is separate from its neighbour, and the transverse lattice girders are replaced by ordinary ones of a depth of 30 in. The longitudinal beams are the same as those represented at Figs. 1 and 2, Plate CXXXV.; they are connected top and bottom by an angle iron 4 in. by 3 in., and a vertical trellis of iron plates. Here the two outside lines only are at present laid. The method of proceeding when a pile, as it happened, fell at the crossing point of drain, water, and gas pipe, is as follows:—The pile was erected on two abutments, which rested on a course of concrete, and between which passed the drain-pipe. Across the tops of these abutments were attached by bolts iron bars of a T section, which supported the base of the column.

Locomotives.—The type of locomotive most employed on the New York elevated railroads is represented by Fig. 5; it is constructed at Grant's Locomotive Works, Patterson, U.S. The principal dimensions of the engine are the following:—

Diameter of Cylinder	10 in.
Travel of piston	16 in.
Diameter of driving wheels	28 in.
Distance from centre to centre of the driving wheels	15 ft. 4½ in.
Diameter of the axles	4½ in.
Length of fire-box	3 ft. 5½ in.
Width of fire-box	2 ft. 0 in.
Number of tubes	125
Diameter of tubes	1½ in.
Length of tubes	5 ft. 9in.
Capacity of tender	35 cubic ft.
Total weight	6·8 tons
Weight on driving wheels	5·7 tons

The boilers are of steel plate. The engines run freely in curves of 90 feet radius; a fully loaded train consists of three carriages. The more recent engines have larger boilers the shelter being less, so as to leave a part of the boiler and tender to view.

Figs. 6 and 7 represent the carriages of the elevated railroads, of which the principal dimensions are the following:—

Length	36 ft. 8 in.
Width	8 ft. 9 in.
Between centres of bogies ...	29 ft. 7 in.
Length of platforms	3 ft. 5 in.
Diameter of wheels	2 ft. 3½ in.
Diameter of journals	3 in.
Length of journals	6 in.
Number of seats lengthwise	32
Number of seats crosswise	16
Total	48
Total Weight	9½ tons
Weight per passenger	455 lbs.

The length of seat allotted to each passenger is 19 in.; the seats are covered with leather; the carriage is perfectly ventilated; the ceilings are inlaid with oak and mahogany; it is heated by means of pipes running under the seats; and each carriage is lighted by three lamps.

Figs. 8 to 12 gives the details of the bogies. The wheels are of compressed papier-maché, the distance between the axles being 6 ft. The side of the truck is carried by six flat springs and four spiral springs upon the balanced lever, B, fixed in such a manner to slide, in case of rupture of axles, upon the sleepers, S S.

The peculiar method of central draw-bar adopted for the elevated railroad is represented at Fig. 13. The bars are fixed exactly at the centres of the bogies, the spring being at *r*. The extremity of the draw-bar is guided in a section fixed to the side, on a curve of 90 ft. radius, the lateral displacement of the draw-bars on both sides of the axis of the carriage is about 19 inches.

Eames' Brake is that adopted, which is on the same principle as that of Smith's, and of which the sacks only differ from those of Hardy in not having the cast-iron capsule which protects the india-rubber membrane. These carriages were designed and constructed in the shops of the Pullman Car Company, at Detroit.

The elevated railroads of New York transport annually about 60,000,000 passengers, and would be able, if all the places were filled, to carry about 120,000,000.

The subscribed capital has reached £6,240,000. The average fare per passenger is 7 cents; they charge from half-past 5 o'clock to half-past 7 in the morning, and from 5 to 7 in the evening 5 cents for any distance, and 10 cents during the rest of the day when traffic is not so great. The total receipts per annum amount to £936,000 and it is calculated that the working expenses are less than half this sum. The net receipts after making all deductions is sufficient to pay a dividend at the rate of 8 per cent. upon the working capital.

THE PROJECTION AND CONSTRUCTION OF RAILWAYS—COMMERCIALLY AND PRACTICALLY CONSIDERED.

(*Continued from page* 372.)

THE specification is a document which *ought to be* of the first importance, for it professes to be a law to the contractor, by which he shall be bound, in the execution of the works entrusted to him. Whether it prove so or not, depends upon the people who have the duty of enforcing it, and also in a great measure upon the specification itself.

Great judgment and experience are required, in order to draw a really practical and practicable specification, and its preparation should be superintended by the engineer personally, and in no case should it be left to be compiled by a (technically) uneducated clerk.

Of course every different work will require its special specification, but we will here endeavour to give a general outline, as a guide to the preparation of the complete document.

In the first place, the specification sets forth the name and locality of the railway to be executed, and gives a general description of the nature of the particular contract dealt with, as, "railway and works, including bridges, viaducts, tunnels, roads," &c.; or, "station buildings," or "signals, locking-gear, telegraphs, &c.," and provides that the contractor shall find all materials, work and labour necessary for the execution of all works included in the contract, and also for the execution of all temporary works required during the progress of the permanent work.

Specifications generally are very arbitrary in their nature, thus power may be reserved to omit part of the works included in the schedule, the amount to be deducted on account of such work being determined by the engineer.

Provision is also made that other contractors may be employed to execute other works on the line (such works not being included in this contract) without hindrance from the contractor under this specification.

Power is also reserved to the engineer to vary the course of railway, and also the gradients, from those shown on the general plan and section, wherever it may appear to him expedient so to do.

All temporary fencing and hoarding and other arrangements for the convenience of landowners and tenants to be provided by the contractor, who will be liable for all damage caused by the neglect of proper precautions in these respects.

The permanent fencing and ditches to be executed as shown on the drawings and as described below. (Here should follow a full description of the various fences to be used.)

All plant required for the proper execution of the earthwork is to be found by the contractor, and all soft material which is, in the opinion of the engineer, unfit for embankments, is to be removed from the line at the expense of the contractor; the contractor shall also at his own cost protect the face of the slopes from the effects of any drains, or water courses adopting to that end such arrangements as may be sanctioned by the engineer.

Where any spoil occurs it shall be tipped where the engineer may direct, and any side cutting required shall also be taken as directed by the engineer, without an additional charge being made.

It may also be provided that should suitable building materials be found in excavating, the contractor may be at liberty to use such materials, but making good at his own expense any deficiency which may be thereby caused in the quantity of materials required to form the embankments.

The embankments to be carried forward of the proper form

and of such dimensions as may subside to the correct dimensions, such drains to be formed on and under them as the engineer may consider necessary. The trimming of the banks to the proper slopes, to proceed as the banks advance.

When the foundation of an embankment is on sloping ground, benches or steps shall be cut (after the removal of any soft surface ground that may be present), and where necessary, trenches cut three or four feet wide and deep, and filled in with concrete, also trenches shall be cut transversely at suitable distances and filled with broken stone to form drains to drain the bottom of the embankment, all at the cost of the contractor.

Any earthwork of unusual size, or having anything about it of a special character should be separately described in the specification. All public, private and occupation roads to be properly metalled, as shown on the drawings; and the making and maintaining of highways to be to the satisfaction of the local authorities of the parishes, &c., through which the railway is intended to pass.

Bridges of all descriptions are specified to be made of the dimensions defined by the Railway Acts and by agreements made with landowners or others, and any large or peculiarly important work is to be separately specified.

The qualities of materials to be specified as "all bricks used to be good, hard, sound, and well burnt, plastic made, and to be soaked in water hours, the courses to be laid in bond and no joints to *more* than $\frac{1}{4}$ in. thick, every course set solid with mortar and well grouted; no broken bricks to be used in any part of the face except for closing a course. In all battered walls the beds of the courses shall be at right angles to the batter. Where necessary the bricks to be moulded."

All stone used in the works to be of good quality, and from such quarries as the engineer may approve. It shall be free from flaws and all other imperfections, and every stone shall be laid upon its natural bed.

In Ashlar masonry each stone shall be dressed on all sides truly to the forms shown on the drawings, the faces being chisel dressed, pick dressed, or tooled, as the engineer may direct. Where the engineer may think necessary, the work shall be cramped together by iron cramps run with lead or sulphur without extra charge.

Block in course or wall stone masonry to be executed with the same quality of stone as the ashlar, no stone to be less than eighteen inches long, laid in courses 9 to 12 inches thick, with breadth of bed not less than the thickness of the courses. Through bond stones to be set one in every superficial yard measured on the face. Where the work is too thick for through stones, a bond is to be carried through as may be directed by the engineer. All stones to be set in a full bed of mortar and beaten with a mallet, each course to be backed with rubble masonry and the whole grouted.

The mortar to consist of one part blue lias lime and two parts clean sharp sand thoroughly mixed together, and wherever the engineer may think it necessary cement is to be provided instead of mortar.

All foundations to be taken down to a solid bottom, to be approved by the engineer, and, where necessary, piles and concrete to be used. The piles to be of memel timber creosoted with 9 lbs. to the cubic foot, and properly shod.

The concrete used in the foundations to be composed of one part hydraulic lime or cement to $5\frac{1}{2}$ parts of clean gravel. Where asphalte and puddle are used on bridges, the asphalte is to be 's, 1 inch thick, laid on in two thickesses, and covered with six inches of well puddled clay. Where no puddle is used four half-inch layers of asphalte are to be applied, or more at the discretion of the engineer.

Large arches are sometimes specified to be bonded transversely with hoop iron jagged on the edges every 8 in. or so, the size being about 2 in. wide, and No. 13 Birmingham wire gauge.

In specifying wrought iron work, the tensile strength and also the percentage limits of stretching before breaking should be fixed, a fair strength for tensile strain is 22 tons per sectional square inch, and for stretching before rupture not less than 3 per cent., nor more than 6 per cent. of its length.

It is a bad plan to specify any particular brand or makers of iron, as such a course may prejudice certain contractors, who do not happen to be on working terms with such makers, and this may redound to the Railway Company's disadvantage.

The qualities of all rivets and bolts should be specified and the methods of executing the work detailed.

Cast iron is usually tested as to transverse strength, and a fair test for railway structures is that a bar 2 in. deep and 1 in. wide, supported on edges 3 ft. apart shall not break under a central load of less than 28 cwt.

Here should follow the specification of the painting, which should be carefully described.

If the occupation works exceed the number described, in the schedule, additional payment for the same shall be made to the contractor, such payment being determined by the engineer. Additions and deductions being estimated on the basis of a detailed schedule of the cost which is to be furnished by the contractor to the engineer.

If the permanent way is included in the contract its specification should follow here.

Mile and quarter mile posts are to be erected and properly painted four times in oil, also notice boards, &c., &c.

The company should provide the land, and place the contractor in possession of it, and it must then all be fenced in before any works are commenced. The contractor is to provide all land for side cutting, spoil, ballast, or temporary occupation.

The contractor is frequently required to satisfy himself as to the accuracy of the plans and sections supplied by the engineer, and also as to the stability of the structures, the

drawings for which the engineer supplies, thus making the contractor responsible for the accuracy and safety of the whole work. This hardly seems right, for it is throwing the whole responsibility of the work upon the contractor, although the engineer takes the credit (and the fees, too) for the design.

Then follow clauses as to superintendence of works, giving the engineer power to dismiss any of the contractor's assistants to whom he may object; delivery of railway to the company; period of liability subsequent to such delivery, during which the contractor is to uphold the railway; carrying on the contract in case of the contractor's bankruptcy; use of plant and tools provided by the contractors; contractors' sureties for the due fulfilment of contract; payment; disputes to be settled finally by the engineer.

The mode in which the tender is to be made concludes the document. We believe the above to be a fair outline description of the general run of specifications for works such as those of which we are treating, but we will now proceed to make some remarks upon specifications, with a view to showing how they may be rendered more *real* than many of them now are, for it is only too certain that in many cases the specification is a form merely, nothing in fact but a dead letter.

It must be admitted by all sane persons that no agreement which is not in itself rational can be of any practical value, or in reality valid, therefore care should be taken to exclude from specifications anything of a contradictory character.

A specification of work, strictly speaking, should only explain the drawings as to the materials and workmanship to be used, and ought to be distinct from the contract agreement, in so far as modes of payment, settlement of disputes, and other points of like character are concerned; the specification should take cognizance of the technical points, and the contract agreement include the commercial and financial clauses.

The contract agreement should be drawn so as to bind the contractor to execute the work in accordance with the drawings and specification, *as interpreted by the engineer*, and with a liability to such alterations as the circumstances subsequently arising may cause the engineer to make.

We lay particular stress upon reserving to the specification only the straightforward work of describing what is required to be done, and in terms which cannot be misunderstood or twisted, and relegating the tautological torrent of *quasi-legal* conditions to its fittest place, *a legal agreement*.

If, however, the fiscal and practical matters must (by force of an absurd habit), be hashed up together, we may, at all events, guard against irrationality such as appears in the following form:—*First*, the engineer is to have absolute power, his *dictum* is to be final, the contractor is to do nothing without his consent; *i.e.*, the engineer rules the whole work in every respect. *Second*, the contractor is to be responsible for the accuracy, safety, and stability of the works. Now, we ask, can anything be more grossly inconsequent than the second of these conditions? The contractor, who is not allowed to use his own discretion, is to be responsible for that which another man determines. No man would, under any circumstances, submit to such conditions, nor sign an agreement binding himself to them unless he knew that the whole thing was a farce and a blind.

It may be put in this light, the contractor has more experience than the engineer, and is practically better qualified than the engineer to determine the proportions of the structure required; if then this be granted, where is the use of keeping on the engineer and paying his fees, when his, the preliminary part of the business is done, and only the practical work remains.

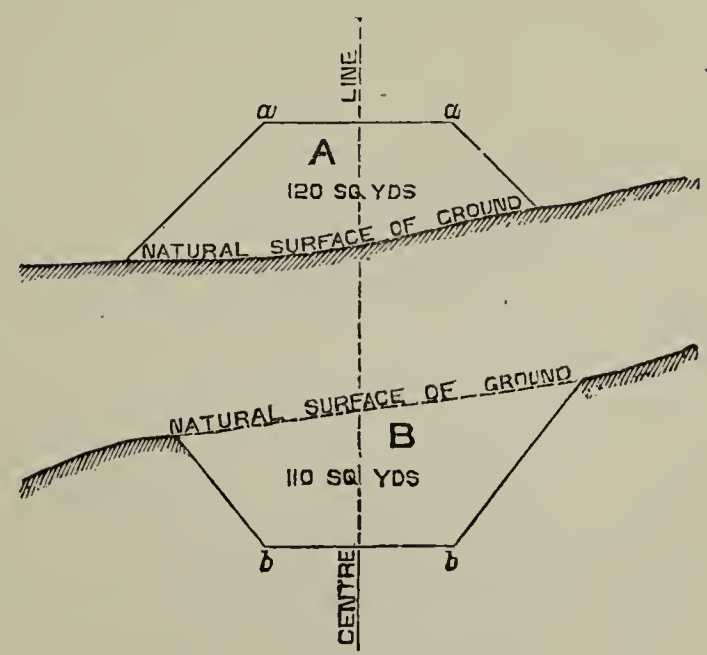
But this question, taken as a whole, ought to be looked more squarely at, and if civil engineers desire to command the respect to which their position and acquirements should entitle them, they must not endeavour to shirk responsibility; it is a sign of a want of confidence in their own abilities and experience, and if a man knows that he is incompetent to carry out a work it is dishonest of him to undertake it.

The specification is accompanied by a bill of quantities, showing the amount of work to be done, so far as it may be determined from the contract drawings.

The land quantities will not be included in the bill of quantities, usually, as the land will be purchased by the company without the intervention of the contractor.

Where there is a large quantity of iron work, it will pay the company better to let it as a separate contract, for if it is included in the general contract, that means putting thirty shillings or two pounds per ton into the general contractor's pocket, and that for doing nothing. The quantities of excavation and embankment are given in cubic yards, calculated from the cross sections, as follows:—The area in square yards of each cross section should be calculated and marked upon it, then the cross sections are taken in sets of three, and thus dealt with. The general forms of the sections of bank and cutting will be, more or less, as shown in Fig. 10, at *A* and *B*, *aa*,

FIG. 10



and *bb*, representing in each case the formation level. Commencing with a cutting, say, at the beginning there is no area, at one chain 120 square yards, and at two chains, 150 square yards, then the mean area for this length of prismoidal ex cavation will be (0 + 4 × 120 + 150), ÷ 6 = 105 square yards, the length is two chains = 44 yards, and the cubic quantity 105 × 44 = 4,620 cubic yards, and so the cutting is taken by lengths of two chains, the cross sections being supposed to be taken at every chain.

The quantities thus determined are scheduled for each cutting and embankment.

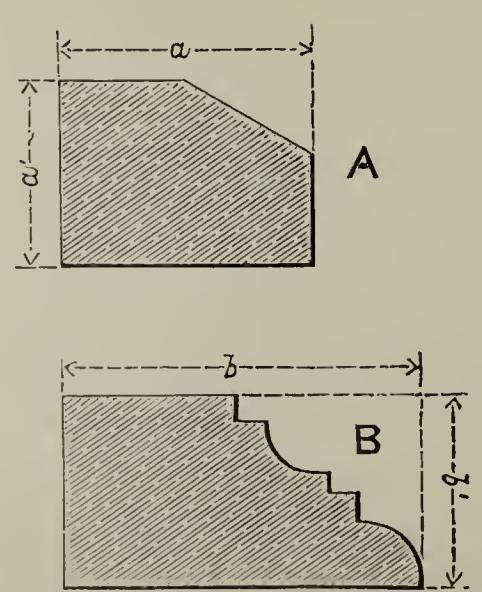
The excavation and embankment for stations, road diversons, approaches, &c., must also be given in cubic yards,

Ballast will be given in cubic yards, but road metalling and other surface work in square yards, the thickness and quality of material being given in each case.

In the permanent way materials, rails, will be given per ton also chairs, fish-plates, bolts, and spikes. Sleepers will be given by number, also keys and treenails.

Fencing, kerbs, and road channels, will be given per lineal yard. Each work should be separately stated in the bill of quantities, thus, for instance, headed, "public road bridge" (over the railway), at twelve miles fifty chains; then follow in order the items, excavation for foundations cubic yards masonry (or brickwork) in abutments, wing-walls, &c., cubic yards ; brick arching cubic yards (or in some cases brick arching is stated in superficial yards, the thickness of course being given); asphalte inch thick square yards ; puddle inches thick cubic yards ; dry lining behind abutments and wings inches thick square yards ; block in course (or brick), parapets cubic yards ; filling over haunches cubic yards ; forming and metalling roadway square yards (kind of metalling described here) ; fencing to approaches lineal yards ; paving inches thick square yards wrought iron girders tons cwts. ; cast iron girders tons c ts. ; floor plates tons cwts ; and any other items that may be required. Opposite

FIG. II



the items are ruled lines for quantities, rates, and money, so that each work is totalled up, and all the totals brought into onegrand total at the end.

All these measurements are taken "nett," but when "ashlar" is used, as for copings, string courses, springers, girder beds, &c., it is given in cubic feet measured gross, as shown at Fig. 11. A, the quantity given, represents the *block from which* the springer is cut, the section is measured on the dotted lines, *a a'*. Again, the section of the moulding, B, is measured along the dotted lines, *b b'*.

For arching, &c., the price includes centering, scaffolding, &c. Also pumping in wet foundations and coffer-damming where necessary.

In some classes of stone work a separate item is inserted for "face-work" stated in superficial yards, and a similar course is sometimes pursued for brickwork. A schedule of prices enables the value of extra work to be determined, as also that of any that may be omitted or varied.

In order to assist the directors in determining upon the acceptance of a contract, it is usual for the engineer to prepare an estimate of the cost of the work, and assuming him to be an experienced man his estimate should come very near the proper amount for good work, for considering the time and care he must have bestowed in examining the country and getting the information necessary to enable him to design the various works he should have a much better idea of their value than a contractor, who can only devote a week or so to the matter.

It does not follow that the most economical plan is to accept the lowest tender, no matter how good the contractor's sureties for the execution of the work may be, for the inconvenience caused by a contractor's failure to complete an undertaking will more than outweigh, in most cases, such penalties as may be recovered. It would be worse than useless, because misleading, to attempt to give any idea of prices here, for they must necessarily constantly vary with localities and with variations of market prices of both materials and labour.

We wish, however, before concluding this section, to point out the advisability of examining well the district in which a project is to be executed, with the view of ascertaining what special materials are there to be found that may be utilized in the construction of the various works required, such, for instance, as stone that may be found in the cuttings, or clay suitable for making bricks, lime for mortar, concrete, &c., in order to save the expense of carriage of materials as far as possible. Care should also be taken, especially in localities where timber is scarce, so to arrange the works that the same scaffolding may be used over and over again in different structures, thus keeping the cost of adventitious work down to a minimum.

V.—Purchase of Land.

The first step towards the actual construction of a railway

consists in obtaining possession of the land required, the freehold of which is purchased, the landowners being compelled to sell under the act authorizing the construction of the railway.

In some parts it is not necessary to absolutely purchase the land passed through thus; the land over a tunnel may be left in the possession of the owner, a right to pass under it only being agreed for. This is called taking an "easement."

The purchase of land involves a great many different points, varying also with the localities. Thus, what may be called an ordinary freehold entitles the holder not only to the surface bought but to all commensurate with that surface above and below; whereas, in other cases, the purchase of the land does not (unless there is a special agreement) entitle the buyer to any minerals that may be found beneath the surface.

It is not necessary, nor in fact usual, to conclude the purchase of the land before starting the works; a "notice to treat" is served upon the owner of each parcel of land required, and possession is obtained, interest being paid upon the value of the land for the time intervening between the period at which the railway company takes possession, and that at which the purchase money is paid.

If, for the purposes of the railway, only a part of a certain field, or factory, or other building is required, the proprietor can compel the company to purchase the whole of it, hence in finally determining the course of the line, care should be taken so to direct it as to avoid, where possible, encroaching upon very valuable property.

With large and influential holders there will most likely be an agreement made before the passing of the Act, hence with them there remains nothing but to fulfil such agreement; but with smaller holders, and especially such as are antagonistic to the undertaking, there often arises a good deal of trouble, and one case has come within our experience in which the landowner avowed his intention (because he could not get exactly his own way) of being as great a hindrance as possible to the execution of the works, and he kept his word most pertinaciously; he was, by the way, an M.P., one of the law-givers of the land.

The final settlement of disputes naturally rests on arbitration, but this, like all other legal proceedings, is best avoided if possible, but in the conveyance of land so many agents and lawyers get mixed up in the matter, that it is not always easy to keep it on a peaceable footing.

In the land arrangements are constantly to be found small scraps, corners of fields, and the like, which being cut off from the remainder are useless to the owners, and are therefore purchased by the company; these are termed "severances," and may sometimes be disposed of by sale to, or exchange with, adjacent owners. In addition to the land required for the railway itself, further land has to be acquired for stations, road approaches, diversions, &c.

Assuming now that we have possession of the land, or, at all events, of some portion of it, we can commence the construction of the line as soon as it is properly fenced in.

VI.—Working Drawings and Execution of Works.

We now come to active operations, which, prior to their being carried out, require the *final determination*, of such moot points as may exist or arise during the progress of the works, and really the most interesting, because the most practical part of the business is now entered upon.

The duties incumbent upon the engineer's staff may be classed generally under three heads; designing the works in the office, making surveys, taking levels, and setting out works in the field, and inspecting the execution of the work, as done by contractors and sub-contractors. The first class of work is carried out in detail by competent engineers, acting under the direction of the engineer in chief; the second, by resident engineers, assisted by engineering surveyors; and the third by men appointed on account of their practical experience in the actual execution of the different classes of work.

The appointment of inspectors is a matter requiring much discretion and general knowledge of character, from the nature of the trust reposed in him, the inspector is naturally at war with all such contractors and sub-contractors as do not execute their work according to specification and drawing; he must therefore be a man of cool, impartial temper, deliberate in decision, and utterly rigid when he, either by his own decision, or by direction of his superiors, has a course clearly set before him; he must not be open to take offence at trifles, and he must be absolutely *incorruptible*.

When we consider thoughtfully the duties of an inspector, we find they involve no small amount of responsibility, and that not altogether of a pleasant character. It is not comforting to feel that one is looked upon as a sort of spy upon the men amongst whom his business life is passed, and yet it does not do to form connections of the nature of ultimate friendships with those over whose actions we are, by the circumstances of our position, compelled to maintain a vigilant watch.

It is common enough to hear people say they admire a man who does his duty; in ordinary life it too often depends upon whether that *duty* interferes with their *interests*.

In coming to the point of *incorruptibility*, we feel we tread upon very delicate ground, but it has to be considered nevertheless.

If the sweeping assertion that "every man has his price," which may be generally applicable in some sense or other, is to be accepted as a commercial truth, then in the case under consideration, it is certainly advisable to ascertain the man's price, and pay it if he be worth it, if not, have nothing to do with him. If a man have long tracts of country to get over, no objection would be made to paying him enough to enable him to keep a horse, because it is necessary to the proper execution of his duties, and on the same reasoning, why should we not remunerate him sufficiently to enable him *to keep a conscience*. There can be no doubt that the safest plan is to put a man above the temptations to

which he must be subjected, and we believe that there are few exceptions to the general rule that a working man would prefer living honestly to pursuing such a course as must inevitably damage his self-esteem; but if his remuneration will barely support him in his position, it is not much to be wondered at if he accepts presents or "treats," when he is wanted out of the way. However, to terminate this unpleasant part of our subject, we will merely say that if it pays the contractor to bribe the inspector, it should pay the company to put him in a position superior to bribery.

The work being ready to be commenced, the resident engineer is furnished with a copy of the longitudinal, which is to be set aside as a "progress section," upon which, as its name indicates, the progress of the works is to be recorded at convenient intervals, showing lengths of cutting excavated and of bank tipped, say every week, or every month, according to the nature of the work; also in like manner lengths of tunnel headings, and break-ups completed, the dates being clearly marked against lines indicating the progress made up to such times. Bridges and other works must also be shown *as executed*, and the dates of their completion given. Furthermore, if it is found necessary during the execution of any work to deviate from the working drawings furnished, all alterations so made should be marked in some distinctive colour upon the *original* drawing, with the least possible loss of time, in order to ensure an exact record of all the works being kept, for prior to the opening of the line, copies of all these works must be forwarded, together with other information, to the Board of Trade, and should the resident engineer omit to keep such a record, he will at the conclusion of the line find himself very unpleasantly placed.

The half-widths (as they are called) of the cuttings and banks having been measured off on the site of every cross section, and lined from one cross section to the next, the turf and top-soil is to be removed and reserved for soiling the slopes of the cuttings and banks, the excavation may then be commenced, and therewith the tipping of the banks upon ground prepared for them, in some cases by the mere stripping of the soil, and in others, as may be found necessary, by trenching and filling in the trenches with broken stones to form drains, and on every side long ground by notching out or benching the ground, so as to form a series of step-like bases, upon which the banks may more securely rest than they would if only heaped up on the side of a hill. Should any slip occur in bank or cutting, it should at once be accurately surveyed and marked on the plan, and its site vigilantly watched for signs of further movement.

THE TRANS-CASPIAN RAILWAY.

THREE years ago Russia's chosen line of approach towards India seemed to be from Tashkend through Samarcand, across the Oxus, and by way of the Bamian pass, to Cabul. It was by this route, writes the *Bombay Gazette*, that General Kaufmann used to correspond with Shere Ali and that General Stolietoff journeyed when, at the head of his political and military mission, he made his famous visit to the Amir. It was from Tashkend, moreover, through Samarcand, and thence to the Oxus, that the Russian brigade advanced which fell back when the news reached Kaufmann of peace, with or without honour, having been definitively concluded at Berlin. Now the whole scene of Russian activity in connection with Central Asian affairs seems to have changed. Tashkend is forgotten for Krasnovodsk; and from the base on the eastern shore of the Caspian missions are despatched, troops are marched, and a line of railway is being pushed forward. If the iron road which, starting from Krasnovodsk, has been finished and opened for traffic as far as Khizil Arvat, had been completed along its whole length, what assistance might have been rendered by Russia after the battle of September 22 to the defeated Ayoub Khan? For it matters little to Russia whether her old *protege* and pensioner Abdul Rahman or his enemy in the field throws himself into her hands, so long as she has an Afghan pretender of some kind to work with. Sooner or later Russia will give support to any Afghan prince who may have a fair chance of establishing himself in Afghan Turkestan. Her official publicists declare openly — though their words were not at the moment of being written intended for any but Russian readers — that Russia will never feel secure in Central Asia until she has taken possession of the fertile provinces between the Hindu Kush and the Oxus, and indeed that without this territory she will not be able to maintain herself at all. Lord Lytton, without precisely encouraging this view, has, in his despatch from Simla of September, 1878, called attention to it, and after citing Colonel Veninkoff's statement that Russia committed a "fatal error" in acknowledging the rights of Afghanistan over Badakshan and the minor states or principalities adjacent thereto, and that "Russia cannot halt in her progressive movement till she encloses

on the south the steppes extending to Khorassan and the Hindu Kush," he adds that this is "no exaggerated picture of the necessity she is under." If Russia committeed what Colonel Veninkoff calls a fatal error when in 1873 she recognized the title of Shere Ali to the Afghan provinces beyond the Hindu Kush, we may be sure that she will at the first convenient opportunity endeavour by direct or indirect means, to repair the blunder; and when the Russian and English Governments interchange despatches once more, as they soon must do, on the subjects of Russia's advance towards Afghanistan, it will be found that our adversaries will base upon the arrangement of 1873 a right to consult only their own interests within the frontier line traced by that arrangement. According to the Russian official view, the acceptance by Russia of the limits forced upon her left her at liberty to annex any territory she might be able to conquer, so long as she abstained from interfering with Afghanistan; and we may be sure that she will profit by the permission which she maintains was accorded to her.

This argument is reserved, no doubt, for a great occasion, but it will in due time be used; and in the Russian official accounts the Khivan expedition is represented as having been undertaken not indeed with the consent of England, but in conformity with an arrangement which, by implication, left Russia at liberty to do what she pleased in Central Asia, so long as she kept clear of the Afghan frontier, as formally recognized by her just before the expedition was despatched. The Russians took, at the same time, the precaution of representing the force sent against Khiva as much smaller than it really was, and engaged not to make any permanent annexation of Khivan territory. But though in the execution of her attack upon Khiva she was guilty of bad faith, and though she derived from its subjection advantages which by a really incredible promise she had undertaken not to secure, she was not precluded by the frontier convention of 1873 from acting at will in the territory untouched by the stipulated limits. Yet though, according to the strict letter of our agreement with Russia, we have no right to complain of the advances she is constantly making in Central Asia so long as Afghan territory is not infringed upon, it is impossible not to watch with keen interest the progress she is so rapidly making towards the point where she must be called upon to halt, and where, for a time at least, she will doubtless halt of her own accord. Meanwhile it would be unfair, perhaps, to lose sight of the fact that the railway from the Caspian to Khizil Arvat is not, according to the Russian published plans, to be continued in the direction of Herat alone. When three years ago Colonel Veninkoff formed the project of a railway from the Caspian to Herat, he at the same time proposed that the line should be continued northwards to Kunduz and southwards to Shikarpur. Thus was to be established the "great natural line of communication" between Western Europe and the British and Russian possessions in the East, and at the same time the shortest line of communication between the Caspian and Samarcand. From Samarcand, through Merv, along the route about to be traversed by the railway, to the Caspian is about half as far as from Samarcand by Tashkend to Orenburg; the distance in the one case being a little over 700 miles, in the other nearly 1,500. It would, indeed, be ridiculous to suppose that Russia's position in Central Asia is merely a strategical one as against British India. She must naturally wish to bind together the points of territory she already holds, and which are at present separated by vast tracts of country more or less impassable. The railway now open from Krasnovodsk to Khizil Arvat is doubtless being constructed for the purpose of bringing the Russian establishments on the Caspian into connection with the stations on the Oxus and ultimately with Samarcand. But the projector of the line proposes to take it to Herat first, and afterwards to Kunduz; and what chiefly concerns England in the matter is the contemplated formation of so much of the line as would place Herat within reach by rail of troops and war material starting from the Caspian.

Apart altogether from the effect that the construction of the Trans-Caspian line may have upon Russia's relations with England, it is curious to contrast the importance attached by Russia to the establishment of railway communication in Central Asia with her neglect of railways already constructed in her European territory. We hear one day of plans for turning the course of the Oxus, canalizing it in its ancient bed, and connecting it by its ancient mouths with the Caspian. The German geographer Keipert regards this scheme as a portentous piece of nonsense, and calls it contemptuously the "great Slavonian sea-serpent." But it is constantly occupying the attention of Russian generals and politicians, and it has been treated very seriously by General Romanoffsky, Tchernaeff's successor and Kaufmann's predecessor in Turkestan. Another set of military and political projectors are bent on the construction of a railway from the Caspian to the Aral sea; and yet another iron road from Orenburg to Tashkend, 1,350 miles long is proposed. The railway meanwhile from the Caspian to Herat is being actively proceeded with; and while Russia is thus spending money on a line which is nothing if not strategical, she does not possess in her corn-growing districts at home the means of sending to the Caucasus for exportation to foreign countries the wheat for which so ready and so remunerative a market would be found. The St. Petersburg correspondent of the very journal whose Merv correspondent has lately given such important information in regard to the progress of Russia along the Attrek, telegraphed on the 24th September that in Central and Southern Russia immense quantities of corn were available for export, but that there were serious drawbacks in the

difficulty of transport, and that "the insufficiency and inefficiency of the railway service were notorious." He adds some remarks on the incompleteness of the Russian railway system, not only in the corn-growing districts, but in the country generally. In Russia, however, politics—and above all foreign politics and the politics of strategy—take precedence of everything else; and the only part of the Russian dominions for which money can be spared with a view to the construction of railways is that which borders the territory of Persia, and which is gradually being brought into contiguity with Afghanistan.

(To be continued.)

RAILWAY SIGNALLING.

FACING-POINT LOCKS.

(*Continued from page* 387.)

BEFORE quitting the subject of "locking-bars," it may be interesting to notice some few other equivalent devices, constructed and operating substantially on the same principle as the original contrivance, already described, and only differing in matter of minute details.

Fig. 149, Plate CXXXIII, is such a device., as designed by Mr. F. Brady, of the South-Eastern Railway, for similarly preventing the points being moved during the passage of a train over them. It consists of a vertical bell-crank rod or bar, G, with a conical head-piece, or of uniform angular section, and which is connected with the point actuating gear. It will be at once manifest, upon referring to the drawing, that the head-piece is held immovable by the flanges of the passing wheels, and the point gear thereto connected consequently rendered inoperative, but when it is released it may be moved out or caused to reciprocate at right angles to the road (as shown by the dotted outline), so as to clear the wheels. At Fig. 150 is shown a similar contrivance, devised by Mr. Buck, of the Brighton Railway.

According to this arrangement, a plate or bar, H, is provided to fulfil the same functions, and holds the point gear immovable during the passage of a train by means of the flanges of the wheels maintaining the plate or bar in the depressed position. When the points are cleared, the plate or bar may be moved out at right angles to the stock-rail, A, by straightening the position of the link, *h*, as also represented by the dotted outline in the drawing. However, these devices are not so simple and efficacious as the original "locking-bar" first described, as their continuity of action is, in some cases, lost, or obtained by more cumbersome and less reliable mechanism.

At Fig. 151 is illustrated a very simple contrivance for interlocking points with distant or other signals. The arrangement is on the "bolt or plunger principle' previously referred to, and will be readily understood upon referring to the drawings.

A prolonged rod, with a flattened end, C, is made to project from the points into a chair on the guide block, *a*, fixed parallel to the road. A parallel rod, *b*, united at one end, is arranged to work in a boss formed on the guide block, *a*, in a direction at right angles to that of the flattened rod, *c*, which has an annular aperture formed in it, to receive one limb of the parallel rod, *b*, when it is moved into the proper relative position for its reception.

The longitudinal parallel rod, *b*, is connected at one extremity to the signal-pull, and at the other to a similar wire or connection for communicating the motion to the usual counterweighted lever on the signal post. According to this simple method, it will be understood that the distant or other signal cannot be pulled "off" unless the points have been already correctly moved, for, unless the points have been so set, it is impossible to pull the limb of the rod, *b*, through the flattened point-rod, *c*, and thus the movement of the one is rendered dependent on that of the other.

In the drawing, the rod, *b*, is shown as pulled through the aperture in the point-rod, *c*, and in which position the points would be locked and the signal "off;" when the signal lever in the cabin is returned to its normal position, the counterweight on the post pulls "on" the signal, and, by such movement, draws the rod out of the aperture, thus releasing the points.

At Fig. 152 is shown an early type of facing point-lock devised by Mr. J. Saxby, and consists in the use of sliding wedge blocks, in a somewhat similar manner to that already described with reference to Mr. Stroudley's early contrivance.

$C\ C_1$ are the sliding wedge blocks, which are worked to and fro in a longitudinal plane by means of crank connections attached to the rocking spindle, D. At the end

of this spindle are attached suitable rods and levers, E *e*, for working the points and also the main connecting rod, F, so that both the points and lock are actuated by the one and same source of motion.

In the drawing, the points are shown standing and locked right for the main line, and, for this purpose, the one block, C, will be observed to have passed into the slide, *f*, so as to wedge the tongue of the point rail hard against the web of the stock rail, while the other block, C, maintains (by an extension or projection formed on it) the point rail sufficiently clear of the opposite stock rail to allow ample clearance for the flanges of passing wheels.

In order to set the points for the branch line, the converse action is effected in an exactly similar manner, and therefore it will be at once observed that it is necessary to arrange the crank connections at about right angles to each other, so that when one block is forward the other is almost withdrawn, and *vice versâ*.

One of Messrs. McKenzie, Clunes & Holland's arrangements for locking facing points, is represented at Fig. 153. The point rails, B B, are moved by an independent rod (and lever) as shown, the locking being effected by two vibrating cam pieces, worked separately by extensions of the main and branch signal gear, so as to alternately wedge the proper tongue against the relative stock rail.

In the drawing, the points are shown as set right for the main line and the respective signal lowered to indicate such condition of the road to the driver of an approaching train, and in which position they are secured by the cam piece, so long as the main signal remains "off." If the points are not thus set or imperfectly moved into such position, it then becomes impracticable to lower the main signal. When both signals are placed at "danger," both point tongues are unlocked, and therefore free to be moved. No locking bar is shown in the drawing as being adopted in this arrangement, but it is obvious that such essential appliance could be easily annexed.

Fig. 154 illustrates a facing point lock by Messrs. Stevens & Sons, of the Darlington Signal Works, the principal peculiarity of which is the employment of a movable locking bar, R, similar in configuration to a check or guard rail, which in its normal position is maintained in close contact with the inner edge of the stock rail, A, by the connections, *r*, and counterweight, S. This bar is moved laterally away from the said rail when it is desired to lower the signal for the main or branch lines by means of the two rods and cranked connections, C and D, which engage with the slotted bar, E, formed with a goose-neck lock, *e* (see enlarged detail), at a suitable intermediate position thereon, and connected at its opposite end with the bar connections, *r*, and the counterweight, S. The rods, C and D, and their connections are virtually prolongations of the main and branch signal gear, so that the movement of the points and signals may be made, to a certain extent, dependent upon each other.

The points, B B, are actuated by a separate lever and connection, *b*, as shown in the drawing, while a subsidiary rod, F, is provided in connection with the point tongues to work in a guide block at right angles to that of the rod, E. This rod has two holes formed in it so that the goose-neck lock or bolt, *e*, may be caused to enter one or the other of them, according as the points may be set right for the main or branch line. Thus it will be understood that as long as the locking bar, R, is away from the stock rail, the points are securely locked by the bolt holding the point rod, F, which also ensures them being in the proper position for the reception of the train signalled. The bar having been caused to assume such position it cannot be interfered with during the passage of the train, because the flanges of the passing wheels are interposed between it and the stock rail.

When the signal is returned to its danger attitude, the bolt, E, is withdrawn from the rod and the locking bar, R, closed by virtue of the before-mentioned balance weight, *S*, connected to a small piece of chain or wire working over a little pulley.

However, as the goose-neck bolt locks the auxiliary point rod in precisely the same manner for both main and branch lines, there is no immediate or certain means of ascertaining whether the points have been moved into the actual position intended.

At Fig. 155 is illustrated a facing-point lock, designed by Mr. Kelly, of Liverpool, the practical efficiency and recognition of which we are personally unacquainted, and, therefore, it is more especially introduced to exemplify the analogy of later appliances.

A locking-plate, C, is arranged to slide in guides cc_1, carried by the sleeper, the said plate being formed with a curved slot, D, in which works a stud or projection, *d*, on the tongue connecting bar. At the opposite end of the plate are fixed two hooked projections, ee^1, the one suitably situated in advance of the other, and which may be so moved by the sliding plate as to cause one or other of these projections to enter corresponding apertures, EE^1, provided in the transverse bar, F. The ordinary "locking bar," *R*, is connected to this sliding plate by the bell-crank lever, G, and auxiliary rods, $g\ g^1$, while, g^2, I and J, are in communication with the signal-gear, with which they are interlocked in a rather complex manner, not shown. The working connections, *H*, *h*, h^1, by which the points are actuated and locked, are represented to the right hand of the figure.

In the drawing, the points are shown as set for the main line, in which position they are effectually locked by the following operations. The sliding plate, C, is drawn forward in the position shown by the working connections attached thereto, and in communication with the signal-box, by which transverse motion is imparted to the stud, *d*, so as to cause it to travel in the slot, D, in a direction at right angles to the motion of the plate, and thereby force over the points. When this has been effectually achieved, the continued motion of the plate thrusts the projection, *e*,

into the aperture, E, in the tongue-bar, and thus they are firmly secured in their proper position. At the same time the "locking bar" has been moved over by suitable connections, by which sequence of operations the proper signal is allowed to be given. In setting the points for the branch line, exactly the reverse action takes place, *i.e.*, the stud, *d*, is caused to travel over to the opposite side, on the plate being pushed in, which similarly withdraws the projection, *e*, and inserts that of e^1 into the aperture, E^1, thus forcing and securing the points over in the opposite direction to that shown.

The actuation of the combined apparatus is effected by one lever and its connections, as will be understood upon reference to the drawing.

Another type of facing point lock is illustrated at Fig. 156, and the design of Mr. T. E. Harrison, Chief Engineer of the North-Eastern Railway, on which line it is extensively used. According to this arrangement, the point rails, B B, are wedged in their proper position by means of sliding blocks, S S^1, (somewhat similar to the early methods of Stroudley & Saxby) actuated by a rocking spindle, T, worked by a separate locking gear rod as represented in the drawing.

The points are moved and set by a special and independent rod and lever as shown, but the rocking spindle may also be so connected as to serve as auxiliary means of assisting the points into their proper positions. In the drawing, the points are shown as being actuated by the usual rods and bell crank levers, but the mechanical device represented at Fig. 157 is frequently substituted to fulfil this office. It consists, as will be seen, of a longtitudinal sliding plate, D, provided with a cam shaped slot, *d*, into which takes a stud or projection formed on an extension of the tongue cross rod, E, so that as longitudinal reciprocating motion is imparted to the sliding plate by the ordinary point rod connections, the points are caused to receive a similar motion in a plane at right angles to the same. R is the locking bar, connected with the other portions of the apparatus, for securing the immovability of the apparatus during the passage of a train, and which is somewhat differently arranged to those already noticed. That is, the bar is fixed to horizontal links or arms, *r*, and, therefore, moves to and from the stock rail in the same direction, instead of rising in a vertical plane. In this case the locking action derived from the passing train is due to the flanges of the wheels preventing the bar being alternately moved to or from the stock. This arrangement of locking bar, however, has a more restricted action and necessitates a nicer adjustment of the parts, and their motion, than the original vertically rising bar.

Fig. 158 represents Mr. J. Bailey's facing-point lock as successfully used by the Midland Great Western Railway of Ireland, and other Irish Railway Companies. (Plate CXXXIV.).

This type of lock resembles those already described, inasmuch as it relates to measures for securing the points at their tongues in addition to the interlocking precautions observed in the signal boxes.

It consists of two of the usual locking bars, A A, of suitable section, which are arranged on the inner sides of the stock rails immediately in front of the points, L L, as shown in the drawing. The rear ends of these bars are pivoted to the rails by pins and radius links, while the front ends are provided with wedge-shaped terminations, which grasp and overlap the tongues of the points.

B is a rocking shaft provided with cranks and connecting rods, J, for actuating the point and locking gear. The point or switch box, E, contains a cranked rod or inclined bar, F, which serves to work the points by means of the rod, H. Before shifting the points, it is absolutely necessary that the locking bars, A A, should be lifted high enough to permit of their wedge terminations clearing the top of the point rails, which, as they descend, grasp the tongues, and so firmly secure them in their proper position.

The "locking bars" are made about 16 or 18 in. long, and are fixed about two inches below the top of the stock rails so that the flanges of the wheels of a passing train effectually prevent the bars being lifted so as to release any of the actuating apparatus, until the train is absolutely clear of the points.

According to this combination and method of actuation, one lever and its connections are sufficient for moving both the points and locking bars, instead of providing two separate levers and independent gear for effecting the same purpose, as in some arrangements.

This, and similar arrangements, are obviously more simple in construction and action and rather less expensive; but there are some further considerations which have to be taken into account, and which, as already stated, we shall subsequently lay before our readers, in order to discriminate between the comparative advantages of other systems.

At Fig. 159 is illustrated Messrs. Saxby & Farmer's (of the Kilburn Signal Works) facing point lock and detector, as extensively used by the Great Northern, Great Western, South-Western, London, Chatham & Dover, and many other of our leading railway companies.

This very popular type of facing point lock is worked by a separate lever independent of the point actuating gear, as and for the particular object hereafter specified, and it is one of those arrangements to whichwe previously referred, as having distinct advantages to be taken into careful consideration in contra-distinction to those in which the whole apparatus is solely worked and controlled by one and the same lever and connections.

A A are the main or stock rails; B B the point rails worked by the separate connection extended to a lever within the signal cabin which is suitably interlocked with the conflicting signal levers in the usual manner.

C^1 is a square locking plunger or bolt which is caused to receive a longitudinal reciprocating motion at or about right angles to the movement of the points by means of the rods and bell crank connections shown, so that it may be caused to enter one of two holes or apertures provided in the stretcher or

cross bar, D. The distance between the said holes in the cross bar which are to receive the plunger should be equal to the stroke or extreme movement of the points, at the particular radius at which the bar is fixed. The plunger has a stroke of about 8 inches, but it should never be withdrawn from the cross-bar more than $\frac{3}{4}$ of an inch, while its square section must be carefully retained, any tapering of its sides being highly detrimental, as the plunger might under such conditions enter the relative hole in the bar when the points were imperfectly moved.

The original type of locking bar, R, is coupled up with this portion of the apparatus, and with which it is simultaneously operated by the connecting rod, *r*, attached to the bell crank lever also working the switch locking mechanism.

The normal position of the locking bar should be about $1\frac{3}{4}$ in. below the top of the stock rail, so that when at half stroke it will be about level with the top of the rail.

The connections between the operating lever in the signal box and the point lock should have at least a uniform travel of 5 inches throughout their length, which movement may be advantageously increased at the last crank as represented in the drawing. It may be worthy of notice that when the extent of these connections exceed a distance of 100 yards, the rollers over which they travel, and are supported, should not be placed at more than 6 ft. apart.

It will now be understood that the points must first be properly set with relation to the stock rail before the signal can be given for a train to approach, as it is not possible to actuate the signal gear unless the locking lever is free to be moved over by the plunger entering one of the apertures in the cross bar. The points having been properly set, and consequently the signal allowed to be given, they are firmly and immovably secured in such position during the passage of the train, so that all jolting and jarring vibrations are minimized, while all power of "splitting" the train is removed from the pointsman in charge.

Upon referring to the drawing it will be seen that two entirely separate connections and levers are employed for working the points and locking apparatus, which necessarily means some small additional expense, this, however, is disproportionate to the advantage obtained. For it will be at once appreciate, that in arrangements economizing the second lever and working by one set of connections, there is always the liability of total failure, and should any individual part break down, there is no immediate means of indicating or detecting such dangerous condition of affairs. Further in the sudden event of such an accident, it might be rendered possible to move a point lever, and thus free the relative signal levers as under normal conditions, although perhaps the points had never been moved by the customary movement of the lever, or only imperfectly set.

According to this second lever system, the one lever and its connections are caused to serve as a dictator or annunciator upon the functions and conditions of the other, so that a failure in the working of the facing points or the locking is immediately detected upon operating the levers.

It may be interesting to observe that on the Isle of Wight Railway Messrs. Saxby & Farmer's facing point locks are exclusively employed in all cases where the points are so located and arranged as to be worked from boxes. In other situations in which they are not capable of being so manipulated, and are located within the distant signals, they are locked by Messrs. Stevens & Sons' 'sword bolts," actuated by the wires of such signals. The essence of the contrivance is substantially similar in arrangement and operation to that elementary device illustrated at Fig. 151.

To the sword bolt (simply so designated on account of its form and section), is attached a dwarf semaphore point indicator, at a distance of about three feet therefrom, and provided with the usual spectacles and lamp for night service. This signal or indicator is so arranged as not to be acted upon until the sword bolt has passed through the locking plate, and so secured the points in position, which having been accomplished, the arm is then allowed to be lowered or pulled in by a slot device arranged at the bottom of the rod connecting the arm and the lever. In such contrivance the pull on the signal wire might be continued to such extent as to pull the miniature arm within the recessed post without detriment. In a similar manner, the "up and down signals," at St. John's Road (Isle of Wight Railway), are controlled by slot and disengaging devices, *i.e.*, the "up home signals" are controlled by a slot from the "north cabin" and the "down home signals" by a slot from the "south cabin," the distant signals having their action similarly governed. These arrangements, however, are really those of the London and South-Western Railway Company.

As will now be understood, one of the most popular forms of facing point locks adopted at the present time is the employment of a locking bolt in the orm of a bar or rod of various sections, worked by rods actuated by a lever in the respective signal cabin, which bolt holds the point rails in their proper position, by passing into one, or one of two, apertures formed in the tongue strut or cross bar. The point levers being also suitably connected with the interlocking apparatus in the cabin to prevent the wrong signal levers being moved (and thus allow an incorrect signal) until such aforesaid locking bolt has been shot into the proper relative aperture, provided in the cross bar, so as to insure the points being moved and locked in their proper position. The before-described locking bar being also suitably connected up in the immediate proximity of the points, to form a dependent element of the combination so arranged as to prevent any of the connected point gear being moved during the passage of a train over the points. Such appliances based on this and similar principles are of the utmost value in the safe

working of facing points; but although they present great security, yet it is not to be expected that any mechanical appliances can be absolutely infallible. For it is obvious that any sudden and unexpected breakdown of the working parts must temporarily destroy their concurrent and sequential action, and so, for the time being, remove their power of control. It will, therefore, be at once appreciated that any form, construction and arrangement of such apparatus that will at once tend to indicate or detect by its abnormal condition or position any dangerously impaired portion is most desirable, providing such result is achieved within reasonable cost and simplicity of action. We have already directed attention to Messrs. Saxby & Farmer's ingenious and popular facing point lock, and the advantages obtained by their arrangement at comparative small increased expense.

We will now pass on to briefly examine another recent form of facing point lock (shown at Fig. 160), invented by Mr. H. O. Fisher, of the Taff Vale Railway, and similarly devised with the view of enhancing their security. If, as already mentioned with reference to some arrangements employed, anything goes wrong with the connections between the point rails and the point lever situated in the cabin, the said rails may fail to be moved by pulling the lever over in the usual manner, and further, the locking bolt may then be moved to secure them in such false or incorrect position, thereby leaving the signals free to be worked in accordance with the abnormal or conflicting condition of the road.

To eradicate in another manner this palpable source of dangerous liability, Mr. Fisher employs two locking bolts, C C^1 (instead of one commonly used), arranged to be actuated by the signal levers in the respective box, so as to lock the point rails, B B, in either of their proper positions. The one bolt is shot when the main line signal is lowered, the other conversely when that of the branch line is lowered, and in either case the signal is entirely controlled by the prior accurate and relative movement of the points. For otherwise, assuming the points to have been incorrectly or insufficiently moved, then upon one or other of the locking bolts advancing it would fail to meet or coincide with the hole or aperture, *c*, (see transverse section) provided in the stretcher-bar for its reception.

The names of the respective working connections of the two locking bolts are printed on the relative parts, represented in the drawing so that their action may be distinctly traced.

According to this arrangement, the locking must take place in correspondence with the signal thereby allowed to be given, as there is only one hole, *c*, in the stretcher bar to receive the bolt, while the connections between the signal levers and the bolt is such, that raising the signal does not cause the bolt to be withdrawn.

The withdrawal of the bolt is only effected by the movement of a special lever located in the signal cabin. Thus it will be understood that the shooting of the respective bolt is performed by the movement of the signal levers while a special lever is provided for the auxiliary and permissive function of withdrawing it.

In order to strengthen the points or switches and avoid them getting out of gauge, a double, overlapping, or divided stretcher bar is sometimes employed, provided with the usual hole or perforation to receive the bolts.

If, at any time, it should happen that the point rails should get of gauge, it would, under this arrangement, be of no momentous consequence, as the hole in the bar would not coincide with the movement of the locking bolts, which, therefore, could not be shot, and so the signal would be prevented from being lowered or taken "off."

The usual locking bar, R, is fixed beside the stock-rails AA, in advance of the point rails, BB, and suitably connected with the other portions of the apparatus, so as to render the points immovable during the transit of a train over them.

The London and North-Western and the Midland Railway Companies are about the only two railway companies in this kingdom which at present manufacture all their own signalling appliances. Formerly, the first named company had all their signalling arrangements carried out for years by the well known firm of Messrs. Saxby & Farmer, of Kilburn, which have deservedly earned a wide-world reputation in this department of railway engineering. This colossal railway company, however, decided some few years ago to manufacture all their own various appliances, and, therefore, accordingly erected extensive shops at Crewe, in connection with their other magnificent works, so as to be able to manufacture every description of apparatus necessary for carrying out the signalling arrangements of their whole system.

All the work produced at this establishment is of a "standard type," and special machinery of the best and latest design has been erected in their shops to ensure the greatest expedition and accuracy, combined with the most economical form of production, consistent with excellent material and workmanship. From time to time, many novelties have been introduced and adopted by this company's signal department at Crewe, some being variations of approved principles, and others merely modifications of details, in order to obtain greater simplicity of construction or action. And a very large proportion of such inventions and improvements have been attributed to Mr. Webb, the company's able chief mechanical engineer.

This company prefers to use iron or steel point connections of channel section, joined by fish plates placed in the channel, instead of the hollow tubular rods and screw sockets generally employed. This arrangement and section of metal is extremely light and strong, and runs

with little friction over the guide rollers, which are of somewhat special design, very easily moulded and cast.

One apparent advantage in this type of connection is the facility for detecting decay or corrosion upon the surfaces, which are well exposed to view, whilst no external examination of such tubular connections could detect or ascertain the amount of corrosion that might have been going on upon the inside surfaces, which might have extended so as to enormously diminish its strength, without giving any outside signs. Further, the channel section is admirably suitable for resisting any buckling tendency under compression.

The present standard facing point lock of the London and North-Western Railway Company was invented by Mr. F. Webb, in 1876, and is so constructed and arranged as to simultaneously and separately lock both point rails when in their correct position. Previous to this arrangement, their point locking was effected by bolts entering holes in a cross bar connecting the point rails, and in the event of its being broken, the pointsman was liable to suppose that the points were correctly locked, when really, in fact, only the broken connection was secured.

According to their present arrangement of "Point Lock and Detector," the operator in the signal cabin at once receives an intimation of any failure which may have taken place in the point connections.

Fig. 161 and 161[a] illustrate a plan and longitudinal section respectively of this apparatus, in which A A are the stock or main rails, B B the point rails connected by the cross bar, C, actuated by the ordinary rods (*c*) and separate lever located in the relative signal cabin. D is a cast-iron box secured to the sleepers in a plane parallel to the rails, the box being fitted with a sliding plate, *d*, capable of receiving a reciprocating rectilinear motion by means of the rod, d_1, attached to it and to one arm of a lever, d^2, having its fulcrum on a sleeper. The other arm of this lever is attached to a rod; which is in connection with an independent locking lever situated in the cabin in the usual manner.

In the plate, *d*, there are formed two rectangular slots or wards, E E^1, into which take the bent ends of the "detectors," F F^1, the one detector being jointed to one point rail and the other to the other point rail, as shown. The ends of these detecting bars rest and slide in notched or grooved bearings formed in the sides of the box, D. In the plate, *d*, there is also provided a cam or curved slot, G, that engages and acts upon a smaller friction roller, *g*, mounted on a stud carried by one arm of a lever, having its fulcrum pin secured to the side of the box, D, in any ordinary manner. The other arm of this lever is connected by a rod to the usual locking bar, R, mounted on radial arms carried by the stock rail. The detectors, F F^1, and the sliding plate, *d*, are held in their places by a suitable lid or cover, bolted to the body of the aforesaid box.

Before the position of the points can be altered, the lever which actuates the locking plate, *d*, must be first brought to its middle position. This movement is so arranged as to act upon the locking mechanism of the levers within the cabin in the ordinary and well-known manner, so that the required signal levers are locked, while the point lever is freed.

By further movement, the middle part of the rectangular slots in the plate, *d*, are caused to assume a position opposite to the ends of the detectors, F F^1, whereby the points can be moved over by the locking lever in the cabin being pulled fully over so as to complete its stroke. The sliding plate, *d*, is then free to be moved to its extreme position, and the lever locking mechanism is so arranged, that this plate must be first moved by its lever into one of its extreme positions, and the points thereby securely locked, before the intended signal with relation to the road can be lowered from its "danger" attitude, while the other conflicting signals at variance with the road prepared remain securely locked at "danger."

The movement, in either direction of the locking or sliding plate, cannot ensue without also raising the ordinary locking bar suitably coupled to this apparatus, which thereby prevents the possibility of the plate, *d*, with its locking gear, being moved during the passage of a train over the points.

It will now be understood that any failure which may take place in the point connections are at once indicated to the pointsman, and further renders it impossible for him to turn a train any way but that which he intends it to travel. Take, for example, the case of an ordinary junction, the facing points of which is fitted with the usual points lock, viz., the stretcher bar and plunger. The road in its normal position lays for the main line, a train is due for the branch and the operator pulls his lever over, intending to make the road for the branch. Suppose a fracture occurs in the point connection during this operation, and the points do not move as intended, the road therefore remaining for the main line. The operator being unaware of this failure, pulls his plunger lever over, so locking the points for the main when he thinks they are set for the branch line; he is now free to lower his branch line signals, but the train of course takes the main line, and thus a serious accident might easily ensue. It will now be understood that with the aid of the "point lock and detector apparatus," just above described, the above state of things referred to could not occur. For, take the case again, the points are set for the main line, and the operator wishes to make the road for the branch, he has first to pull his locking lever *half* over (he cannot get it further), then he pulls his point lever over, and finally completes the stroke of his locking lever, in order to release his signals; this done he is sure that the road is made and securely locked for the branch. But now supposing the point rod or the stretcher bar fractures, the matter would stand as follows:—the road is set for the

main as before the operator pulls his locking lever half over then pulls over his point lever, but the point rod has broken and the road still stands for the main, he essays to complete the stroke of his locking lever, but the points not having moved he cannot do this, and thus receives an intimation that from some cause, the points have failed to act properly or obey the movement of his lever, but his signal lever still remains securely locked at "danger."

There is nothing very special to be observed with regard to the Midland Railway Company's point locks, further than to state that all their signalling appliances are manufactured at their own works at Derby. In fact, this company is the only one that has never employed a signal contractor to do any of their works, but have for more than twenty years made all their own necessary appliances, introducing from time to time their own engineer's improvements and modifications.

Their "standard facing point lock" consists of the usual locking bolt and bar, which are so connected with the point actuating gear that one lever and its connections serves to both move and lock the points, being substantially similar to other arrangements hereinbefore noticed. It will, therefore, be readily understood that the locking bolt and lifting bar being both worked by the movement of one lever in the cabin, the bolt is withdrawn from the slot or hole in the switch bar, the points then shifted, the bolt again shot into an aperture in the switch bar, and the locking bar lifted and lowered, all during the movement of the one lever.

The locking bar (which is of the original type) was usually made about 18 ft. long, but now an additional short bar of about 8 ft. long is attached thereto at about 6 ft. from the one end, so that this compound locking bar cannot be raised at intervals between the passage of wheels of the present "long bogie" and similar vehicles in which the span between the wheel base is in some cases 32 ft. We have previously directed notice to the slight economy of expense and labour attained in busy districts by the arrangement of working points and their locking gear by one lever, but their inferior safety over those employing separate levers and connections.

At Fig. 162 is shown a simple method adopted by the Midland Railway for locking some of their facing points as may be seen for example at Nottingham Station. B B are the point rails actuated by the ordinary switch rod, C, and bell crank connections, the said switch rod being arranged to work in a guide block, D, more clearly shown in the enlarged detail, and provided with a suitable hole or holes, for receiving a prolongation, E, of the respective signal gear. This arrangement is on the same principle as other devices already explained—*i.e.*, the employment of sword or plunger bolts, for securing the proper position of the points, and for obtaining a mutual control over the relative signals.

In this manner, the simple contrivance represented is caused to operate so that the points must be first properly and sufficiently moved with relation to the stock rails before the relative signal can be lowered by virtue of the play allowed to the said prolongation when capable of entering the coinciding aperture provided in the switch rod.

If the movement of the points is incorrect, or attempt made to give a wrong signal, the thrust transmitted to the signal rod does not meet its relative aperture in the switch rod, and thus a conflicting signal is prevented from being given.

Fig. 163 represents a facing point lock considerably used by the South-Eastern Railway Company, and the invention of Mr. F. Brady, their chief engineer.

This lock will be readily seen to be of an analogous nature to that early device of Messrs. McKenzie & Holland's already described, in fact it is substantially the same with the addition of a locking bar of peculiar arrangement. The point rails, BB, are moved into their proper position for the branch or main line by the rod, *b*, in the usual manner, and when so moved the relative signal can be lowered, which thereby causes one of the clamps or cams, CC^1, to be moved over one of the point tongues and so firmly secure it in its correct position. In the drawing, the points are represented as set for the main line, and in which position they are secured by the clamp, C^1, which has been moved over the relative tongue upon the lowering of the main line signal.

It will now be obvious that the points must have been first properly and sufficiently moved before such action could have taken place, and from which position they are incapable of being altered until the main line signal is taken off. Exactly the reverse action takes place with regard to the branch line, and this part of the arrangement will be seen to be identical to that of McKenzie's early method of locking previously referred to.

To render the points immoveable during the passage of a train their actuating gear is suitably connected with a locking bar, *R*, which is caused to make a slight circular reciprocating motion to and from the stock rail about a centre, *r*, upon any movement of the points. In the enlarged detail it will be seen that the locking bar, R, is of curved section, so as to fit snug up against the web and side of the stock rail, and which is connected by arms to a boss or sleeve fixed to a horizontal rocking spindle, *r*. To this spindle is keyed a small arm to which the points are suitably connected by any convenient arrangement of rods and levers.

It will now be understood that any movement of the points will impart a vibrating motion to the locking bar, so that if the flanges of the passing wheels of a train prevent such play during their transit, the whole apparatus must be effectually secured against any careless or accidental movement of the points.

(To be continued.)

(*Continued from page* 355.)

TABLE I.—(*continued.*)

1	2	3	4	5	6	7	8	9	10	11	12	13
No. of Piece.	Makers.	Application.	Year made.	Modulus of Elasticity. Kg. per sq. mm.	Limit of Elasticity. Kg. per sq. cm.	Breaking strength. Kg. per sq. cm.	Contraction of Area per cent.	Elongation in 25 cm. (10 in.) per cent.	Analysis. Carbon per cent.	Sulphur per cent.	Phosph. per cent	Remarks.
52a	Bochum Mining and Steel Co.	Axles	—	—	—	5140	49	24.2	0.31			Very fine grain, ashy appearance.
52b	ditto	ditto	—	—	—	4960	52	24.6	0.31			As above.
66	ditto	Locomotive DrivingAxle	1873	2 255 000	2340	5500	47	17.8	—			Very fine grain, glittering, with dark fibrous focus.
67	ditto	Locomotive Leading Axle	1873	2 275 000	2340	5250	48	19.6	—			Ditto, ditto. Both these showed dangerous cracks in shank, 32 mm. deep, after running respectively 16,070 & 107,800 km.
62a	Borsig, Berlin	DrivingAxle	1855	2 274 000	1030	3900	19	—	0.29	0.00	0.104	Very coarse crystals, with whitish dirty flaws. Ran from 1855 to 1879, then broke at work. Arsenic considerable.
62b	ditto	ditto	1855	2 303 000	970	3870	50	—	0.24	0.00	0.1076	Fibrous, with some crystalline points. Arsenic considerable.
23	Sächs SteelWks. Döhlen	Pins for Loco-Wheels	1877	2 268 000	4070	9600	6	—	1.11			Uniform fine grain, with small grey focus just at centre. Good material for pins, &c,
39a	Falkenroth, Kocher & Co., Haspe	Axle	1867	2 270 000	1340	5080	56	—	0.42	0.03	0.0652	Very fine grain, quite fibrous. Good material.
39b	ditto	ditto	1867	2 256 000	1350	5230	52	20.7	0,34			Ditto, ditto.
4a	Fr. Krupp, Essen	Locomotive Axle	1865	2 253 000	3360	9050	23	—	0.64			Fine grain, with focus. Experience very favourable.
4b	ditto	ditto	1865	2 243 000	3490	7490	29	—	0.66			Ditto, ditto.
9a	ditto	Axle	1863	2 326 000	3310	5490	3	—	0.73			Very coarse, uniform grain.
9b	ditto	ditto	1863	2 275 000	1860	6570	7	5.3	0.68			Coarse grain, radiating from one point of circumference.
21a	ditto	ditto	1866	2 304 000	2770	7920	25	8.8	0.87			One-half fine grain, the other much coarser, and with flaws. Good results.
21b	ditto	ditto	1866	2 361 000	2770	7960	28	7.3	0.73			Ditto, ditto.
38a	ditto	ditto	1865	2 357 000	2800	6260	46	14.7	0.43			Very fine grain, with large dark focus. Good results.
38b	ditto	ditto	1865	2 330 000	2800	6210	48	14.8	0.37			Ditto, ditto.
42a	ditto	Locomotive Axle	1872	2 322 000	3000	6420	38	—	0.55	0.02	0.0456	Very fine grain, with large dark fibrous focus.
42b	ditto	ditto	1872	2 302 000	3210	6370	42	—	0.54			Fine fibre throughout.
47a	ditto	Wagon Axle	—	2 350 000	2490	5380	45	—	0.30			Very fine grain, with large dark fibrous focus in middle. Broken in an accident, after running 191,602 km.
47b	ditto	ditto	—	2 257 000	2590	5850	48	23.7	0.28			Similar to above.
55a	ditto	Carriage Axle	1857	2 280 000	3360	5500	54	13.9	0.44			Fine fibre, ashy and grey appearance. Axle condemned, after running 629,873 km.
55b	ditto	ditto	1857	2 304 000	2650	5500	48	14.8	0.43			Very fine grain, with large fibrous focus.
6a	Ruhrort Steel Wks.	TenderAxle	1876	2 324 000	2650	6770	28	—	0.49			Uniform fine grain. Very uniform and good in working.
6b	ditto	ditto	1876	2 225 000	2660	6560	34	16.8	0.55			Fine grain, with large dark eccentric focus, Results as above.

1	2	3	4	5	6	7	8	9	10	11	12	13
No. of Piece.	Makers.	Application.	Year made.	Modulus of Elasticity. Kg. per sq. mm.	Limit of Elasticity. Kg. per sq. cm.	Breaking strength Kg. per sq. cm.	Contraction of Area per cent.	Elongation in 25 cm. (10 m.) per cent.	Analysis. Carbon per cent.	Sulphur per cent.	Phosph- per cent.	Remarks.
63a	Werner, late Carlswerk, Neustadt	Werner's steel axle	—	2 310 000	5090	7440	1	—	0.91			Fine grain, with crack lengthwise 4 mm. by 0.75 mm. Been in use 20 years.
63b	ditto	ditto	—	2 273 000	5090	6720	2	—	1.03			Fine grain, with crooked crack 11 mm. by 1 mm., and smaller crack at edge.
B.—TYRES (Round Test Pieces).												
20a	Bochum Mining and Steel Co., Bochum	Tyre	1874	2 232 000	4680	8250	—	—	0.43			Uniform fine grain. Broke in neck. Good in working.
20b	ditto	ditto	1874	—	—	8350	31	—	0.44	0.02	0.0707	Uniform fine grain. Much arsenic, boiling up in phosphorus test, and bearing a grey solution.
26a	ditto	Tender tyre	—	2 331 000	4240	8020	14	—	0.90			Uniform fine grain. Broke in neck.
26b	ditto	ditto	—	—	—	8210	23	—	0.80			Fine grain, with eccentric focus.
29a	ditto	Locomotive tyre	1863	2 071 000	2090	3030	0	—	0.34			Coarse grain, piece had various flaws and deep holes on outside. Broke through one of these, with dark fracture, as if stained with oil.
29b	ditto	ditto	1863	2 263 000	2890	7400	7	4.2	0.73			Coarser than last, but without flaws. Both these tyres had worked well.
41a	ditto	Tyre	1873	2 261 000	1850	3650	50	—	0.38			Fibrous, very porous.
41b	ditto	ditto	1873	2 253 000	1620	3890	49	26.0	0.14			Similar.
50a	ditto	ditto	1861	2 223 000	3030	5950	13	—	0.65			Uniform fine grain, with flaws in casting.
50b	ditto	ditto	1861	2 230 000	2170	5690	6	4.8	0.45			Very fine grain, dirty honeycomb at side, with holes originating from outside, which was there cracked.
58a	ditto	Locomotive tyre	1872	—	—	7310	9	8.2	0 52			Fine grain, radiating from honeycomb at centre.
58b	ditto	ditto	1872	—	—	6610	—	3.1	0.52			Fine grain, radiating from spot at edge. Broke in neck.
15a	Falkenroth, Kocher & Co., Haspe	Tyre	1875	2 294 000	3520	6980	34	—	0.52			Very fine grain.
15b	ditto	ditto	1875	2 244 000	3460	7230	35	17.6	—			Very fine grain, radiating from spot at edge.
25a	Hörder Mining Co.	Tender tyre	—	2 314 000	3970	6930	23	—	0.62			Very fine uniform grain.
25b	ditto	ditto	—	2 261 000	3800	6990	29 32.5 at groove	19.6	0·54			Very fine grain, like fibre, radiating from one point on edge. Broke at slight groove left in turning, and not filed. Greatest contraction not at fracture.
1a	Fr. Krupp, Essen	Tyre	1873	2 150 000	4350	8490	7		0.90		0.0636 Solution quite clear, a little arsenic, mangan. 0.35	Very uniform fine grain, radiating to centre-pop at neck, where it broke. Test piece had been forged at red heat. This piece and next from a tyre which broke in the solid, at slow speed and on good road, after running 83,000 km., 1,277 since last turning. Thickness at fracture, 45 mm. Slight frost for one or two days. Leading wheel of a six-wheeled carriage. Strong skeleton, with spokes.
1b	ditto	ditto	1873	2 194 000	4480	8960	10		0.82			Two-thirds fine, one-third much finer grain. Short, deep crack in former.
2a	ditto	ditto	1872	2 196 000	2920	5580	49		0.40			Very fine grain, dark focus. Mangan. 0.28, trace of silica and arsenic. Tyre quite worn out.
2b	ditto	ditto	1872	2 243 000	2770	5500	41 48 at least section	18.1	0.37			Very fine grain, one segment fibrous.
3a	ditto	Tender tyre	1871	2 239 000	3160	7490	31.5		0.69			Fine grain, with dark focus. Homogenous metal.

1	2	3	4	5	6	7	8	9	10	11	12	13
No, of Pieces.	Makers.	Application.	Year made.	Modulus of Elasticity. Kg. per sq. mm.	Limit of Elasticity. Kg. per sq. cm.	Breaking strength. Kg. per sq. cm.	Contraction of Area per cent.	Elongation in 25 cm. (10 in.) per cent.	Anaylsis. Carbon per cent.	Sulphur per cent.	Phosph, per cent.	Remarks.
3b	Fr. Krupp, Essen	Tender Tyre	1871	2 276 000	3210	7970	30	15.2	0.71			Fine grain, eccentric focus, Homogenous metal.
5a	ditto	Tyre	1873	2 271 000	4500	7440	4		0.83			Fine grain, radiating from one point at edge. This and next from same tyre as 1a and 1b on last page.
5b	ditto	ditto	1873	2 251 000	4500	5670	1	0.5	0.89			Very coarse grain, somewhat cracked and porous.
7a	ditto	ditto	1874	2 325 000	3130	6520	11	11.6	0.63			Very coarse grain, radiating from point on edge. Tyre broke in working.
7b	ditto	ditto	1874	2 331 000	3260	5600	3	2.0	0.61	0.02	0.1125	Same as last,
8a	ditto	ditto	1869	—	—	6520	52	22.5	0.26			Very fine grain, dark focus.
8b	ditto	ditto	1869	—	—	6620	49	21.3	0.26			Similar.
12a	ditto	ditto	1871	2 318 000	3490	7340	33	15.9	0.64			Very fine grain, somewhat eccentric dark focus. Quantity found satisfactory.
12b	ditto	ditto	1871	2 328 000	3190	7440	29	13.5	0.72			Same as last, but focus at edge.
19a	ditto	ditto	1874	2 320 500	3570	8600	26	13.7	0.70			Fine uniform grain, no focus. Good material.
19b	ditto	ditto	1874	2 284 000	3570	8710	9	11.2	0.67			Coarser grain than last, radiating from point on edge. Good material.
22	ditto	ditto	1877	2 326 000	3600	8210	31	14.5	0.74	0.04	0.039	Fine grain, dark eccentric focus. New material.
24a	ditto	Tender Tyre	—	—	—	5000	65	24.7	0.11			Extraordinary fine grain, angular fracture.
24b	ditto	ditto	—	—	—	5080	64	25.0	0.11			Same as last.
28a	ditto	Locomotive Tyre	1874	2 265 000	1540	6780	35	—	0.82			Not very fine grain, dark eccentric focus, tyre had lasted well.
28b	ditto	ditto	1874	2 190 000	1530	7080	31	16.2	0.84			Very coarse grain, small eccentric focus, same tyre as last.
40a	ditto	Tyre	1872	—	—	7370	35	9.9	0.58			Fine grain, large dark eccentric focus.
40b	ditto	ditto	1872	—	—	8120	27	10.5	0.58			Same as last.
46a	ditto	ditto	1871	2 328 000	4350	7510	14	14.	0.55			Fine grain, radiating from flaw at edge. Working results good.
46b	ditto	ditto	1871	2 300 000	3620	7350	21	14.4	0.49			Same as last.
48a	ditto	Wagon Tyre	1869	2 256 000	3600	8470	5	4.0	0.79		0.0725	Fine grain, radiating from small flaw at edge. Arsenic strong. Tyre ran 344,783 km. from Aug., 1869 to Dec. 1874, and then broke at a flat worn by brakes.
48b	ditto	ditto	1869	2 273 000	3600	8110	3	3.2	0.79			Same tyre as last, grain coarser.
49a	ditto	Locomotive Tyre	1868	2 260 000	3280	9090	17	6.4	0.73			Very fine grain, finer at one part, with small fibrous focus. Leading tyres had run 280,300 km. from 1868 to 1876.
49b	ditto	ditto	1868	2 232 000	3230	9000	12	7.6	0.71	0.03	0.0359	Same tyre as last, very coarse fracture.
53a	ditto	Tyre	1868	—	—	6520	2	2.1	0.80			Very coarse grain, adiating from spot at edge.
53b	ditto	ditto	1868	—	—	7850	25	6.8	0.73			Very fine grain, small eccentric fibrous spot.
59a	ditto	Locomotive Tyre	1874	—	—	5850	42	16.5	0.31			Very fine grain, large dark focus.
59b	ditto	ditto	1874	—	—	9320	20	8.8	0.83			Very coarse grain.
60	ditto	Tyre	1877	2 252 000	3820	7590	31.5	—	0.81			Very fine grain, with dark focus.
61	ditto	ditto	1877	2 277 000	2890	6670	31.5	—	0.70			Not so fine, with sharply defined dark eccentric focus.

(To be continued.)

OFFICIAL REPORTS ON RECENT ACCIDENTS.

Major Marindin has reported the result of his inquiry into the causes of an accident which occurred on the 12th June, at Farnham junction, on the London and South-Western Railway. It is difficult to determine with any degree of certainty what was the cause of this accident. Owing to the contradictory evidence it is even doubtful which vehicle in the train was the first to leave the rails; for the driver and the fireman state that it was the leading carriage which did so, some yards after passing the first crossing west of the facing points of the loop, and that the engine did not run off until at the second crossing, 182 feet further to the west; while, on the other hand, the signalman, who was looking at the train approaching, is quite positive that the ballast was flying out in front of the engine soon after it passed the first crossing. It is quite certain from the marks that the right wheel of some vehicle struck the end of the fixed point of the first crossing, and ran on the wrong side of it, and then over it into the ballast between the two rails at the heel of the point, the west end of the check rail being pulled across out of place, and the fastenings of the check chairs drawn out or broken. This could only happen from one of two causes: either the gauge of one pair of wheels must have been very much too wide, or the check rail opposite to the point of the crossing must have been lying too far from the running rail, possibly on account of one or more keys falling out. The evidence is to the effect that all the wheels were true to gauge, and is equally strong that the gauge of the line was correct, and that the keys securing the check rail were nailed in. It should be observed that the first chair which showed the great strain upon the check rail was beyond the point of the crossing, while immediately opposite to the point there was no mark of any binding against the inside of the check rail, or any broken chair, or any sign of any wheel having run over the top of the rail. If a pair of wheels had been so much out of gauge as to run on the wrong side of this fixed point with the check rail in proper position, it is hardly possible to conceive that they could have run so far without accident at other crossings; and it is more probable that the accident was mainly due to the check rail being out of place at this acute crossing, where there is an interval of three feet between the shoulder of the wing rail and the point of the crossing, for which distance the only thing to keep the right wheel upon the line is the check rail upon the other side. Judging from the fact that the train, after it had left the rails, ran for no less than 250 yards, the speed must have been considerably over 20 miles an hour; and I have no doubt that the engine was the first vehicle to leave the rails. Although the engine wheels were in very fair order, yet there were found four or five plates in the springs which had been broken before the accident happened, and therefore the weights were probably uneven, and the engine consequently lurching more than it should do. Taking all the facts of the case into consideration, I can only surmise that this accident must have been caused by the check rail at the first crossing being sufficiently out of place to admit of the flange of one of the right wheels of the tank engine, running at a high speed, and lurching considerably, to take the wrong side of the fixed point of th crossing. It is most fortunate that, after leaving the rails, the engine and other vehicles kept towards the six-foot side until they had passed under the over-bridge, and were thrown across to the outside of the line by a cross-over road, for had any of the carriages struck the abutment of the bridge the consequence would probably have been very serious.

Colonel Yolland has reported the result of his inquiry into the circumstances which attended the fatal accident that occurred, on the 15th June last, to a person crossing the line rather more than a quarter of a mile on the western side of the Sittingbourne station of the London, Chatham, and Dover Railway, who was knocked down by the engine of a train from Sheerness to Sittingbourne, and so severely injured that he died on the following morning. It appears that on the evening in question, as the 9.15 p.m. train from Sheerness to Sittingbourne—consisting of a tank-engine and two carriages—was travelling on the down main line and passing this foot-path crossing about 9.31 p.m., the engine knocked down and seriously injured a person, Henry James Williams by name, by breaking his left arm in two places and seriously injuring him internally, so that he died about 8 o'clock the next morning. The driver of the engine states that he was standing on the right side of the engine, and he was therefore in the most favourable position in which he could be placed for seeing a person passing from the south wicket gate for foot passengers across the up line towards the down line and north wicket gate, but that he saw no one. The view from an engine approaching the Sittingbourne station on the down main line would be limited to a little over 100 yards, in consequence of a curve in the line farther west than the crossing. The driver says that it was a dark dry night, and the platelayer who had seen the deceased at the south wicket gate from the north wicket gate says it was twilight. It is stated that the deceased was deaf, and that in consequence thereof he is supposed not to have seen or heard the Sheerness train as it was approaching the crossing. I do not consider that any blame for this accident attaches to any of the servants of the Company, and

I am unable to discover any grounds for the verdict of "Manslaughter" brought in by the jury at the Coroner's inquest against the London, Chatham, and Dover Railway Company. It is true that a man committed suicide whilst of unsound mind by placing himself in front of a down express train on the 3rd May last, and was run over and instantly killed at this same footpath crossing. It is also remarkable that there are two other footpath crossings besides the Charlotte Street crossing in the immediate vicinity of Sittingbourne station, one on the eastern and the other on the western side of the station, and that neither of these footpath crossings is mentioned in the details received by the Board of Trade from the late Mr. Joseph Cubitt; and the presumption is that they did not exist when the line was opened for traffic in 1858. I have been unable to obtain positive information on this subject, but fatal accidents have occurred at each of these footpath crossings, and the Company's engineer, Mr. Mills, has informed me that the Company has determined to do away with the one at the eastern end of this station by making a subway through the embankment. The other footpath crossing on the western side of the station is equally objectionable, as foot passengers have to ascend and descend by steps the embankment, which is about 30 feet in height, so that a subway might readily be made; and all danger to persons in crossing the railway would thus be avoided, and the risk to individuals crossing the railway at the Charlotte Street footpath crossing might be avoided by an over footpath bridge, and by doing away with the wicket gates.

Major-General Hutchinson has reported the result of his inquiry into the circumstances connected with the collision which occurred on the 6th July last, at Wymondham North Junction, on the Ely and Norwich section of the Great Eastern Railway. This collision between an unattached engine, running on an experimental trip (after repairs) from Norwich to Wymondham, and the 11.57 a.m. down passenger train from Wymondham to Tivetshall, as the latter was crossing the main up line at Wymondham North Junction, was caused by the want of proper care on the part of the driver of the unattached engine. This engine (No. 247) was fitted with an automatic Westinghouse brake, actuating blocks on the four hind wheels of the engine and the six wheels of the tender, as well as with the ordinary tender hand-brake. The driver, Binnie, had acted in that capacity for 10½ years, and had been in the habit of driving for the past two years a precisely similar engine to No. 247. On the present occasion two previous stops had been made at Trowse and Hethersett when the air brake had acted well. The engine left Hethersett at 11.52 a.m., and on approaching Wymondham North Junction, Binnie found both the up distant and up home signal against him, these signals being visible for a long distance off. He most likely assumed, in the first instance, that these signals were at "danger" in consequence of the section between Wymondham North and South Junctions being blocked by the train for which he had been stopped at Hethersett, and consequently, expecting the home-signal to be taken off, he was approaching it at so high a speed that, notwithstanding the powerful brake at his disposal, he overran the home-signal by a distance of 35 yards, and came into collision with the engine of the passenger train on the junction crossing, his speed being at the time seven miles an hour, according to his own account, or 20 miles, according to that of the train driver. As the air-brake had been acting properly at Hethersett a few minutes previously, and was, I am informed by the locomotive superintendent, found to be in proper working order after the collision, I cannot credit Binnie's statement that he applied it half-way between the junction distant and home signals, or some 500 yards from the point of collision, and that, finding it was not taking effect, he himself (his fireman being engaged with the injector) applied the tender hand-brake, and got it full on just as he was passing the home-signal, and that he had no time to reverse. It would rather appear that the air-brake was applied when the engine was close to the home-signal, and that the driver, seeing that there was then not time enough for it to take effect, endeavoured to supplement its action by himself applying the tender-brake. This collision shows that the working of the block system, as carried out at Wymondham North Junction, where the rules permit that "line clear" may be given to Hethersett for a train due to stop at Wymondham when the main up line is being crossed, is not sufficient to insure the safety of the public. This requires that the up line should neither be crossed nor fouled when "line clear" has once been given to Hethersett, and *vice versa*.

Colonel Yolland has also reported the result of his inquiry into the circumstances which attended a collision between two passenger trains, that occurred on the 15th July last, at the London Bridge station of the South-Eastern Railway. From the statements it appears that the 4.52 p.m. down passenger train from Charing Cross to Dartford, on the afternoon of the 15th ultimo (which consisted of a tank engine, nine carriages, and two brake carriages with two guards), stopped on the east down line, alongside of the London Bridge platform, about 5.19 or 5.20 p.m., according to the driver at the usual place; and it is allowed that the engine did not stand clear of the covered way, which it should have done, in accordance with the instructions issued for the guidance of the Company's engine-drivers, as follows:—"Down trains calling at London Bridge.—Engine-drivers of trains on the east down line must take their engines clear of the covered way." The engine-driver states that his engine did not stand clear of the covered way when they stopped, and that the covered way was 6 feet ahead of where his engine stopped, and he did not know where the tail of his train stood when it stopped at the London Bridge station. "Line clear" was given back for this train from the E. F. signal-box to the Borough Market signal-

box at 5.19 p.m. while the 4.52 p.m. down Dartford train was still standing alongside of the London Bridge down platform, and the signalman on duty in the E. F. signal box took on the 5.2 p.m. down passenger train from Charing Cross to Tunbridge at 5.19 p.m. The 5.2 p.m. down train consisted of a tender, engine, and 16 vehicles, including two brakes, with two guards riding in them. It approached and passed the E. F. signal-box about 5.21. This train was intended to be run on to the west down line at the London Bridge station by means of the cross-over road having facing-points on the east down line, 38 yards south of the E. F. signal-box. The signalman in the E. F. signal-box states that he did not take off the stop-signals for the train to run into the London Bridge station, because he could not set the facing-points over for the train to pass to the west down road; and that happened in consequence of the driver of the North Kent (or Dartford) train having stopped his train, so that some vehicle stood over the advanced locking-bar. He says that he tried to move the (facing) points, and could not move them; he tried twice, and that it was the last vehicle in the Dartford train that stopped over the advanced locking bar about 18 inches. He also stated that trains have stopped on that locking-bar many times before, but it had not produced any accident since he had been employed in that signal-box, between five and six years, and the locking-bar has been there all that time. The evidence is contradictory as to the 4.52 p.m. down train having stopped with the last vehicle standing over the advanced locking-bar on the east down line, and the length of the engine and train does not at all correspond with the distance between the end of the covered way (over the down platform) and the advanced locking-bar; but I see no reason whatever for doubting the statement of the signalman in the E. F. signal-box as to his having been unable to shift the facing-points of the cross-over road. But the collision was undoubtedly caused by the gross negligence of the driver of the 5.2 p.m. down train in having deliberately run past the E. F. down stop-signals, both standing at danger, at considerable speed, without having had any hand signal shown to him out of the E. F. signal-box to warrant his passing these signals, in consequence, as it is alleged, of such an objectionable and dangerous practice having been authorized by a former superintendent of the line. Still the collision would not apparently have taken place but for the fact of an advanced locking-bar having been placed opposite to the trailing points of the cross-over road on the west down line, and this advanced locking-bar being interlocked with the facing-points of that cross-over road so that they could not be shifted while a vehicle was standing on the down east line over the advanced locking-bar, and be set right for the cross-over road for the turning of the 5.2 p.m. down passenger train to cross from the down east to the down west line. The arrangement appeared to me to be so objectionable that I applied to the general manager of the South-Eastern Railway to know what the object of having an advanced locking-bar in such a position could be; and I annex his reply; which, however, does not appear to me to afford any sufficient grounds for putting in such a locking (advanced) bar. The present general manager could have had nothing to do with the putting down of this advanced locking-bar, as it occurred many years since. On this occasion, in combination with the negligence of the engine-driver of the 5.2 p.m. down passenger train in running past the down stop-signals standing at danger, it caused this collision. It appears that the driver did not discover his mistake until he was within about two carriage lengths from the rear of the 4.52 p.m. down train into which his train ran, and hence if the train had been fitted with continuous brakes, as it should have been, it is probable that they would not have exercised any influence on the result.

Colonel Yolland has also reported the result of his inquiry into the circumstances connected with the collision that occurred on the 8th of August last, between New Hey and Shaw stations, near Oldham, on the Lancashire and Yorkshire Railway, between a special passenger train from Rochdale to Oldham and Manchester, and a train of thirty-six empty carriages, which was in slow motion, backwards, towards Rochdale, on the up line of railway. From the statements it appears that, on the occasion of the Oldham wakes or general holiday, it was determined to convert the up line of railway between Shaw and New Hey stations, on the Oldham and Rochdale branch of the Lancashire and Yorkshire Railway, into a siding for the reception of a number of carriages, 200 being required for running ten excursion trains, and a general order was issued by the superintendent of the line on the 4th August authorizing the blocking of the line between 11.30 p.m., after the passage of the last passenger train, on the 8th, until 6 a.m. on the 9th August, and directing that the whole of the traffic between New Hey and Shaw North cabin should be worked over the down line in charge of a single-line conductor. The Chief Inspector of Traffic, Thomas Baildon, was instructed to carry out these arrangements; and he appears to have to commenced to collect the empty carriages at Shaw station, and to have altered the hour at which the single-line working was intended to commence from 11.30 p.m. to about 8.45 p.m. on the night of the 8th August, without the authority of the superintendent, and to have deputed assistant Inspector Pimblett to make the necessary arrangements for single-line working between New Hey and Shaw stations, and Inspector Baildon subsequently proceeded to block the up line between Shaw North cabin and New Hey station, and was about to travel with the train of empty carriages (36 in number) towards New Hey station when the collision took place, about 9.50 p.m. Assistant Inspector Pimblett saw Inspector Baildon in the Shaw North cabin, and also the signalman (Worrall) there, and he then proceeded with goods guard Fitton, who was to be made single-line conductor, to New Hey station, went in the signalman's cabin there, and filled in three forms, similar to that given in the evidence; one intended for the signalman at New Hey, a

second for the single-line conductor Fitton, and a third for the signalman (Worrall) in the Shaw station North cabin. Assistant inspector Pimblett then returned to Shaw station with single-line conductor Fitton, travelling on the up line, after having the signals for the up line at New Hey disconnected, so that they could not be used. On arriving at Shaw station North cabin with single-line conductor Fitton, he explained to the signalman in that cabin (Worrall) that he was going to establish single-line working, and giving the signalman one of the printed forms, and tying a red flag round the single-line conductor, Fitton. Some conversation then passed as to what was to be done with the 7.25 p.m. goods train from Werneth to Normanton and the signalman (Worrall) said he had wagons to attach to that train; and a bell signal was received at the same time from New Hey, notifying the arrival there of a special passenger train from Rochdale for Oldham. A consultation is said then to have taken place as to whether the Normanton goods train was to go over the single line to New Hey on its way to Rochdale, or the special passenger to come on from New Hey to Shaw; and it was decided that single-line conductor Fitton should go to New Hey for the passenger train; and Fitton states that he told the signalman at Shaw North cabin that he was to put nothing on that road—meaning the up line—until he came back; that he then left the cabin and got on the pilot engine and proceeded to New Hey, and he informed me that he meant to return to Shaw station by the proper up road. On the day after he gave this evidence he directly contradicted it. While the pilot engine, with single-line conductor Fitton on it, was travelling to New Hey, Fitton says that he went to the driver's side of the engine, and said to driver Butterworth (who was killed), "We will not remove this engine off this line after this trip;" but when they reached New Hey, Fitton got off the engine on to the platform, and shouted to the signalman to turn his engine across from the down to the up line, and when it had got to the up line the engine was backed down to the special passenger train, which was standing alongside of the up platform, and the pilot engine was coupled on to the special passenger train engine by one of the firemen, and Fitton gave the word for the train to proceed along the up line on which it was standing. The line is on a sharp curve, and passes under an over-bridge a short distance from the spot at which the collision occurred between this up special passenger train from Rochdale and the train of empty carriages which was being shunted towards New Hey from Shaw station at slow speed, so that the view from the pilot engine and passenger train engine was very limited. The passenger train is said to have been travelling at from twenty to thirty miles an hour on the up line, and the train of empties which was being backed at about three miles an hour. The collision occurred about a quarter of a mile north of Shaw station North cabin. The pilot was thrown off the rails and fell over on its right side towards the down line, and the passenger train engine had the leading and trailing wheels thrown off the rails. Both engines were running with the tender in the front. The collision was the direct result of the mistake made by the single-line conductor, Fitton, in travelling from New Hey towards Shaw on the up line of railway with the passenger train, after he had completed all the necessary arrangements for working the traffic on the down line between New Hey and Shaw as a single line; but inspector Baildon was, in my opinion, greatly to blame for not having himself superintended the commencing of the single-line working, especially as he had most improperly altered the time fixed by the superintendent (11.30 p.m.) to an earlier hour, 8.45 p.m., when the passenger trains had not ceased to run. There is only one other point to which I must direct attention. This is a double line of railway, and I am quite ready to admit that when an accident occurs on a double line of railway, and an obstruction occurs on it, or some necessary repairs are required on one of the lines, single-line working must necessarily be resorted to; but I do not think the Railway Company on this occasion were justified in converting one of their main lines into a siding, and using the other line as a single line for working the whole of the traffic on it. The collision proves that the safety of the public was thus endangered. If such excursion traffic is to be run, proper siding accommodation should previously be provided for it.

Major-General Hutchinson has also reported the result of his inquiry into the circumstances connected with the collision which took place on the 11th of August last at Cromer station, on the Great Eastern Railway. This collision between an heavily-loaded excursion train (consisting of thirteen vehicles) and two empty carriages standing at the end of the dock line into which the train was running, was due primarily to want of judgment on the part of Walter Green, the driver of the train, in over-estimating his power of stopping a heavy train on a falling gradient with a comparatively small amount of brake-power, and rails greasy from drizzling rain. He states that in consequence of the small amount of brake-power and the state of the rails, he shut off steam and had his brake applied some 300 yards sooner than usual, and that he had no fears about not stopping in time till he was passing the signal-cabin (116 yards from the point of collision), when the engine wheels began to slide along the rails; that he tried to prevent this by first easing and then re-applying the brake; but finding this of no effect, he jumped off with a shovel and threw some ballast on the rails, the collision then occurring at a speed of three or four miles an hour. Green appeared to be a very intelligent man, and gave his evidence in a very straightforward manner. His mistake was in not, under the circumstances above alluded to, making an earlier reduction of his speed. He was also to blame for having no sand in the rear sand-boxes, so that he might have used it when running from North Walsham coal bunker first; or had he turned his engine at Cromer before going to North Walsham, he would have had the use of the front sand-boxes on the return journey. Had there been sand in the rear sand-boxes, or had the engine been turned before leaving Cromer, the collision would probably have been

avoided. It would also most likely not have taken place had there been, as the rules of the Company required, a guard in the front brake-van as well as in the rear one. The rule is that there should be two guards with a train of more than ten vehicles, and here were thirteen vehicles with only one guard. The station-master and foreman porter at Cromer are to blame for this infraction of the Company's rules. This was a case in which a good continuous brake, not allowed to be ordinarily used for running into terminal stations, would have been of the greatest service in enabling the driver to rectify his mistake.

Major-General Hutchinson has also reported the result of his inquiry into the circumstances connected with the accident which occurred in the early morning of the 3rd of August last at Heaton Norris station, near Stockport, on the London and North-Western Railway. This accident, in which the up Normanton mail, consisting of engine, tender, and six vehicles, was turned into an up goods line about 320 yards long at Heaton Norris junction, the buffer-stops at the end of the line being swept away by the engine, which then ran up on to the north end of Heaton Norris up platform, knocking down three brick pillars carrying a verandah roof, was caused by the facing-points at the entrance of the goods line not having been pulled over so as to stand right for the branch line, when the signalman moved the lever which should have brought them into their proper position before locking them and lowering the signals for the train to proceed from the up branch to the up main line. The failure of the points to follow the pull of the lever was owing to the thread of a cast-iron adjusting-screw socket having perished from corrosion, and when the lever was moved the socket was pulled from the end of the rod attached to the points, allowing the points to remain open for the goods line. The substitution at facing points of wrought iron sockets for cast iron sockets had been, I am informed, in progress for some time, but in consequence of this accident an order has now been issued that the cast iron sockets attached to facing-points and facing-point locks are to be *at once* replaced by wrought iron ones. This is a very proper precaution, and no unnecessary time will, I trust, be allowed to elapse before the use of cast iron sockets has been done away with. In the present case there were no outward signs to indicate that the thread of the screw had perished; but it was not prudent of the man in charge to have made no internal examination of the socket from time to time, and this does not appear to have been done. Notwithstanding the failure of the point-rod, no accident should have resulted had the brake power with which the train was supplied (viz., a continuous chain-brake, applicable by the driver or guard to the four rear vehicles out of the six composing the train, in addition to the tender-brake and to the reversal of the engine) been fully brought into play. The driver states that his first act on discovering when about 200 yards from the buffer-stops, that he had been turned on to the goods line, was to pull the brake-cord, his speed being about 20 miles an hour; whether he did so or not, the guard, who was sitting close to the brake-cord attachment, and was ignorant that anything was wrong, is confident that the cord was not pulled, and that the continuous brake was not applied. This only furnishes another instance of how little the action of this brake, when required to be used on an emergency, is to be depended on. In a distance of 200 yards, with a speed much in excess of what was stated to have been the case on this occasion, the train, if supplied with a quickly-acting continuous brake, would have been stopped without difficulty.

Major-General Hutchinson has also reported the result of his inquiry into the circumstances connected with the collision which occurred on the 26th August last, at Doncaster station, on the Great Northern Railway. This collision, between the up express train due at Doncaster at 12.55 p.m. and three empty vehicles standing in a siding about 130 yards from the south end of the up platform where the engine of the express train ought to have stopped, can only be attributed to the driver having approached the station at an injudiciously high speed, and then having failed to properly apply the vacuum continuous brake, with which the whole of the train was fitted, and which, had it been used sufficiently early, would no doubt have stopped the train in ample time to have avoided the collision. As the train was approaching Doncaster, the driver had improperly sent his fireman to the front of the engine to oil the lubricators, and he had not returned to the foot-plate before the engine had reached the south end of the platform, where he (the fireman) jumped off and escaped without injury. In consequence of the absence of the fireman from the foot-plate, the driver had himself to apply the tender-brake on finding, as he says, he thought that the vacuum brake was not acting properly; after doing which, as he was passing cabin A, 330 yards from the point of collision, he informed me that he first whistled for the guards' brakes and then reversed his engine. This statement, as well as some others, being at variance with what he had stated at the inquiry held by the company's officers shortly after the collision occurred, I am sorry to say I cannot attach much weight to the driver's evidence, but have come to the conclusion, judging from the other evidence, that, being alarmed at the speed at which he was approaching the platform, he got confused, only partially applied the vacuum brake, and then, coming to the hasty conclusion that it was not in proper order, resorted to the tender brake, and perhaps (though this is doubtful) reversed his engine and got steam against it. There is no reason for believing that the vacuum brake was not in proper working order; the driver himself acknowledges that it worked properly as far as the north end of Doncaster ticket platform; it appears to have put itself on when the cord which was attached to the handle on the engine was tightened, and opened the ejector, as the train entered the siding, which curves sharply to the left; and it was found to be in working order on the train when it was tried with another engine about a quarter of an hour after the collision.

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THE BLACKBURN COLLISION.

We publish in this issue Colonel Yolland's report to the Board of Trade on the collision at Blackburn. The report is a remarkable and an exceptional one. It is remarkable for its uncompromising boldness; and exceptional, because it virtually questions the infallible wisdom of the Board's recommendations with regard to continuous brakes. The startling originality which characterizes this report has rendered it necessary for the Board of Trade to append a special and somewhat apologetic introduction. The vigorous independence of their Inspector has sorely exercised the goverment department so ably presided over by Mr. Chamberlain. When Mr. Chamberlain inaugurated his appointment to office by a formidable circular to railway companies urging them to greater activity in the adoption of efficient brakes, we respectfully ventured to point out that the Board had itself caused delay by setting forth automatic action as a condition of efficiency. With a few exceptions our remarks were echoed by a large majority of able and experienced railway officers, whose replies were almost unanimously to one effect: "Give us a *reliable* automatic brake, and we will at once adopt it." Public bodies, like individuals, learn more by experience than precept, and unhappily in railway management we are apparently doomed to learn every lesson at a fearful cost of human life. Only a few months after the Whitehall admonition had been issued to the railway world, the cruel slaughter of seven unfortunate passengers and the mutilation of sixty-four others at Blackburn station, reminded us that the brake question could not be settled by theoretical "conditions" and official circulars.

The facts connected with the Blackburn accident are probably still fresh in the minds of our readers; but it may be well to recall them. The express train from Manchester, due at Blackburn at 3.14 p.m., arrived about one or two minutes late. The driver stated that he applied the Westinghouse brake in the usual manner, but that it failed to act. He then applied his hand-brake, reversed his engine, and put steam on while in back gear. This was not, however, sufficient to prevent a fatal collision between his train and an engine engaged in shunting a portion of the Liverpool and Todmorden express, which was standing in Blackburn station. Although the custom of allowing two trains to come into Blackburn Station on the same side is one that has been in practice many years, and until the present case, without being the cause of any accident, still we quite concur in Colonel Yolland's remarks that it "would be far better to increase the accommodation at important exchange stations, like Blackburn, and avoid the use of the permissive system altogether where it is possible to do so." That the Westinghouse Brake failed to act when required, Colonel Yolland does not hesitate to assert, and it appears from a report of the Lancashire and Yorkshire Railway, on the 20th April last, that this was not the first time it had failed to do so on that line. On that occasion a passenger train from Manchester to Leeds ran through Stanningly Station, 200 yards! Colonel Yolland's remarks towards the end of his report are of a sound and practical nature. He says:—

"No one can question, I imagine, the desirability of the continuous brakes being made, 'in case of aceident, self-acting,' if that can be accomplished *without introducing any other element of danger.* The self-action can probably do no harm in such cases, and in some may do good, but it is quite a different thing when any of these continuous automatic brakes become self-acting when there is no accident, and suddenly arrest the progress of a train when it is not required by the driver to be stopped; or, on the other hand, refuse to go on and act, from any cause whatever, when the driver desires to pull up his train in order to stop at a 'danger' signal, or at the proper spot at a station, or to avoid any obstruction whatever which he may suddenly come upon, such as cattle straying on the line. No great harm is done, as far as the public safety is concerned, by the brakes suddenly going on without any action on the part of the engine-driver, where the traffic is strictly worked on the absolute block system, and two trains are not permitted to be on the same

section of the line between two signal-boxes at the same time, beyond the delay thus occasioned, which, however, is frequently a great nuisance to the passengers; but the case is altogether different where failures táke place in the working of the absolute block system, or where it is replaced by the permissive system, as through Blackburn Station, and two trains are allowed by the system of working adopted or by mistake on the part of one of the signalmen to be on the same section at the same time, and collisions take place like that in the Bleamoor tunnel, on the Midland Railway, on the 19th August, 1880, when three passengers were injured, and that at Bow-road station, on the Stepney and Stratford branch of the Great Eastern Railway, on the 3rd ultimo, when eleven passengers are returned as having been injured, and the driver and fireman of an engine of the following train sustained fatal injuries, and died on the spot, from the action of the brakes suddenly stopping the leading train where no stoppage was required, and where the engine-driver did all in his power to avoid the stoppage. It is quite true that if the signalmen concerned in both these cases had done their duty in correctly working the block system, the collisions would not have occurred; neither would they have happened had not the trains been unnecessarily stopped by the action of the brakes."

Again he says:—

"The Westinghouse automatic air-pressure brake is a very clever, ingenious piece of mechanism made up of a very great number of separate parts, to give it the automatic action; but, as is well known, the greater the number of parts in any piece of mechanism, the greater is the liability of failure, and I consider that the liability to apply itself when not required, and when there is no accident, and to fail to act or go on when absolutely required by an engine-driver, constitute two grave defects in its present construction.

"Until these defects are got rid of I do not think the Westinghouse automatic air-pressure brake should be employed where the absolute block system of working is not rigidly upheld."

To the list of catastrophes given by Colonel Yolland may well be added that most disastrous of all such accidents which recently occurred between Albany and New York, where eight persons were killed on the spot, and many others maimed for life, and which was caused by the self-application of this "*very clever, ingenious piece of mechanism.*."

Our contemporaries *The Engineer* and *Engineering* have been induced by the bold candour of this Report to publish elaborate defences of the Westinghouse Brake. We will not challenge the beautiful purity of those wells of truth, from which their inspired opinions so freely flow; but in the interest of railway engineers, we must object to such statements as the following:—"A vast experience has shown the Westinghouse Brake to be the *most perfect** in use; this fact is proved by the almost universal opinions of American railway engineers, and by nearly *all the leading railway engineers in this country*, and in France, &c." With regard to American engineers, we will not offer any comments, but it is an unmerited insult to include English railway engineers in this panegyrical frenzy. The engineers of English railways representing 70 millions of miles run out of a total 112 millions, are unanimously in favour of the vacuum in opposition to pressure brakes, and, moreover, the *majority* of these engineers have had ample opportunity of observing the working of the Westinghouse brake on their *own* lines, and have advised their Boards to *discontinue its adoption.*

Our respected contemporary, *The Engineer*, enters into a lengthy description of the beauties of the Westinghouse coupling, but neglects to mention that *since this accident the whole of the automatic couplings in question throughout England have been scrapped*, and replaced by the old form with stop-cock, and that on some lines this is *the sixth* change which has been made in this detail.

Let us remember that in discussing the relative merits of continuous brakes we are dealing with a matter involving the safety of many millions of railway travellers. Let us estimate at its true value the grave responsibility attached to those who offer to educate our leading mechanicians on this important subject, and above all, let us approach it in a spirit of earnest enquiry, rather than with the clap-trap of an "Almighty-dollar," advertisement.

In their introduction to Colonel Yolland's report the Board of Trade have expressed their opinion that they see no reason to alter their views with regard to automatic brakes, although they discreetly suggest "that the companies' attention ought to be directed to the necessity of giving most careful instructions and *warning* to those who are entrusted with duties, on the proper performance of which the due operation of the brakes necessarily depends." We may be excused for expressing some mystification as to the exact application of the word *warning*. Are we to understand that the efficiency of the Westinghouse brake, and the lives of all our railway passengers are to depend on the complete comprehension of additions to the already elaborate instructions issued to guards, porters, shunters, and others, where this brake is in use? Surely in using *such* Automatic Brakes, *we are nullifying the very principle advocated by the necessity of an ever increasing dependence on human intelligence.*

It becomes more and more evident that simplicity and reliability must be the principal characteristics of any successful automatic continuous brake, and toward this end many well-known engineers and inventors are directing their attention.

The whole question is one of mechanical science, and cannot be settled by official manifestoes or newspaper eulogies.

* We need not trouble about the grammar.

RAILWAY SIGNALLING.

POINT-LOCKS.

(*Continued from page* 18.)

AT Figs. 164 and 165, Plate CXXXVI., we further illustrate one of Mr. R. C. Rapier's arrangements for locking railway facing points, whereby one bolt or its equivalent is capable of being shot when the points are in one position, and another bolt or similar device, when they are in their opposite position, the lever and its connections for operating such apparatus being actuated in opposite directions.

In the first mentioned figure two bolts, *a* and *b*, are represented as being so connected with a lever arrangement, D, that the alternate "push and pull" of the rod, E, will cause either one or the other bolt to enter one of the apertures, A or B, formed in the switch bar, C. Assuming then, that the one bolt, *a*, is for locking the points for the "main line" by pulling the rod, E, and conversely the other bolt, *b*, locks the points for the "branch line" by a pushing movement, then by such arrangement the operator in the box will always know by the position of the lever the condition of the points, and if any failure should happen, where it has occurred.

According to the views shown in the latter figure a compound bolt, F, *f*, is provided of peculiar form, working into a similar shaped T slot, *c c'*, in the switch bar, C, whereby the "push and pull" of the locking gear rod, E, operates in a rather different manner. This compound bolt has a projection, F, extending in a horizontal plane, and a similar one arranged in a vertical plane, which fit into corresponding apertures provided in the said switch bar, C. Thus assuming the horizontal locking piece, F, to lock (by its forward movement) the points in their normal position or right for the "main line," then the vertical piece is similarly caused by a pulling movement to pass into the coinciding hole, *c'*, in the switch-bar, so as to secure the points for the "branch line."

On this or analogous principles modern point locks and detectors are constructed, whereby pointsmen, operating in boxes are informed of any failure in the apparatus located some distance from him.

The double-acting point or switch lock of this type and above referred to, was patented by Mr. Rapier in March, 1874, and in October of the same year Mr. J. S. Farmer (of the firm of Messrs. Saxby and Farmer), followed up the principle, and brought out the "facing-point lock and duplex detector," as at present supplied by this firm.

This apparatus is also devised to afford means of prompt detection should any breakage of the connection happen between a set of points and the actuating levers in the cabin. Such a breakage would, according to many arrangements, allow the point lever to be so moved as to unlock the relative signal lever, and thus allow the signal to be taken "off," when actually the points have failed to obey the movement of their lever, and consequently remain in an incorrect position.

This "duplex detector" simply consists of a double-acting plunger which is capable of being "pulled" when the points stand in one position, and "pushed" into a hole or aperture in the cross-bar when they are in the opposite position, in the manner hereafter more fully explained.

The detail arrangements by which such results are achieved may be variously modified according to circumstances or desire, but the principle actually remains unaltered throughout, and, therefore, as an appropriate example, we shall illustrate some of the original arrangements.

Fig. 166 represents a side view of an ordinary point lever, A, and bolting lever, B, mounted side by side in a suitable frame fixed in the cabin, the latter being so arranged as to effect the bolting or locking of the points by a "push or pull" of the connecting rods according to the position of the first-mentioned lever, as shown and indicated by the direction of the arrows, and the dotted line at *a*.

For this object the lever, A, is prolonged below its fulcrum, and is provided with a pin engaging in a slot, formed in a rod, C, the upper end of which has another pin entering a curved link, B^1, B^2, formed in a piece with the lever, B, while its lower end is connected to a bell crank, D, communicating with the point locking apparatus by the rods, E. When the lever, A, is in the position shown in the drawing (which may correspond to the points being set right for the "main or branch lines" as desired) then it will be understood that on pulling over the lever, B, in direction of arrow, the rod, C, will be "pushed" downwards so as to impart similar motion to the point-locking bolt connected to D.

If, on the other hand, the main lever has been moved over to occupy the position shown at, *a*, the rod, C, will be caused to move towards the left, so as to bring it into the position *c*, with its upper extremity engaged at the end, B^2, of the

link. Now upon pulling over the secondary lever, B, in the same manner as before, the rod, C, will be drawn up, and the bell-crank, D, caused to pull upon the rods, E, connected to the locking apparatus in the reverse manner to that first described.

The above arrangement may be variously modified to obtain a similar result, as shown for example at Fig. 167.

In this case, the lever, A, is linked to two rods, C^1 C^2, which are both attached to the crank, D, and are provided with gabs near their upper extremities, as represented. The secondary lever, B, has cross arms, carrying studs, B^1 and B^2, arranged on opposite sides of the fulcrum.

It will now be understood that when the lever, A, is in the one position, the gab of one of the rods, C^2, is engaged on the stud, B^2, but if this lever were moved over to the left, the gab of C^1 would engage with stud, B^1, when the action of the lever, B, on the crank, D, and rods, E, would be reversed.

At Figs. 168, 168*a*, and 168*b*, is presented a plan, part transverse section, and a part longitudinal sectional elevation respectively of a pair of facing points provided with the "duplex lock and detector" above referred to. Fig. 169 is a plan of the switch bar. The locking apparatus is arranged in conjunction with the tppe of "locking bar" shown at Figs. 170 and 171, so as to ensure the immovability of the points during the passage of a train. The bar, R, may be provided with a duplicate set of slotted links, *ss*, as shown in the latter figure, connecting it directly to an arm, T^2, of the lever, T., Fig. 168. The slots in the links permit the bar to travel in either direction from its middle position, so that either the "push or pull" of the rod, E, will cause it to rise during its travel on one of these links.

In the plans of the general arrangement of the apparatus, Fig. 168, AA are the main or stock rails, and BB the point rails, the latter being worked by a separate rod and lever, as represented in previous examples.

The rod, E, is caused to actuate the bolting or locking mechanism by the lever, B, Fig 166, in a distant cabin, which is "pushed or pulled" according to the position of the point lever, A, in the manner already explained. The motion imparted to the rod is communicated to the locking apparatus, F, by the bell crank lever, T, and connecting rod, T^1, as shown in the drawing. If desired a toggle joint or lever may be substituted as a means for transmitting such motion to the bolting plungers.

The locking apparatus, F, is arranged in guides to slide across the point connecting-bar, P^1, through which a pair of holes of different shapes are provided, so as to fit or coincide with the projecting bolts or locks, $f^1 f^2$, Fig. 169.

In the drawing the section of these projections are represented as of T-form (the one being in an inverted position relative to the other), but any other convenient design could be adopted. One of the holes, say p^1, in the cross-bar is arranged to receive one bolt, as for example, f^1, while the other inverted hole would receive the bolt f^2. The distance of these holes or apertures apart is equal to the throw of the points, so that when the points have been moved home into one of the two positions, a "push" of the rod, E, will cause the projection, say f^2, to be "thrust" into the hole p^2, while conversely, when the points are home in their opposite position, a "pull" of the same rod will cause the bolt, f^1, to be "drawn" into the aperture, p^1.

Now, should the points be imperfectly moved, neither "pushing or pulling" the rod will effect the shooting of either bolt, as the apertures in the cross-bar fail to correspond, and therefore such obstruction will immediately intimate to the operator that his points are not properly home. Further, should any of the connections become broken or obstructed the operator would be immediately apprised that the points had failed to obey the movement of his lever, and also would be able to see by the position of the lever, B, in what manner or part the failure had arisen.

It will, therefore, be readily appreciated that if the supplementary or secondary lever be interlocked with the relative signal levers of the system, it is rendered impossible to give an incorrect signal with relation to the condition or state of the road.

The immovability of the points during the passage of a train over them is effected by the connected "treadle locking bar," R, in the manner already described with reference to other similar appliances.

This type of "duplex facing-point lock and detector" is strongly advocated by Messrs. Saxby and Farmer, as fulfilling all the most recent requirements of safety and efficiency, but we are not aware that any of them have as yet been actually adopted by any railway company.

A certain analogy between this class of apparatus and and that of Mr. Fisher's, of the Taff Vale Railway, and Mr. Webb's, of the London and North-Western Railway, &c., will now be apparent to our readers, and as this notice of Messrs. Saxby and Farmer's appliance is given somewhat out of chronological order we think it fair to observe that their apparatus was brought out fully two years before any of the other contrivances of a similar character referred to in our treatise.

At Figs. 172 & 173, are represented two very recent forms of "facing point locks," as designed and manufactured by Mr. George Edwards, C.E., the Managing Director of the Railway Signal Co.'s Works, Fazakerley, and which types of lock are now being adopted by the Lancashire and Yorkshire Railway.

The two plans show an arrangement for locking a pair of junction points. In the first example the point actuating and locking gear is partly arranged outside the metals; while in the second, the whole apparatus is arranged between the rails.

According to these methods, both the actuation of the points and their locking are effected by one lever and its

connections, and in this and other features of construction bear some general resemblance to other point locks already described.

The movement of the points, B B, and the subsequent locking of the same, is effected by the cam pieces, D D′, which are alternately caused by the transverse reciprocation of the notched bar, C, to first move the tongues of the points and then hold them in position. The cam pieces are thus caused to oscillate or vibrate about their centres by their projections engaging at the proper intervals in the corresponding aud relative notches in this bar. These notches and projections lettered *d*. d^1, d^2, d^3, d^4, d^5, will be immediately understood upon referring to the drawing. The usual locking bar, R, arranged along the side of the stock rail, A, is coupled up with the other gear in the manner shown, and the general arrangement of the entire apparatus, will be readily understood upon reference to the drawing.

The revolving clamps or cams employed in this first arrangement for locking the points in their proper position will be noticed to be analogous to those used by Messrs. McKenzie, Clunes, and Holland, &c., in their comparatively old contrivance, and more recently revived by Mr. F. Brady.

According to the second arrangement, the actuation and locking of the points is achieved by a longitudinally reciprocating plate, E, Fig. 173, similar to the device supplied in Mr. Kelly's point lock previously described, although the connections and manner of operating such device are of, perhaps, peculiar character.

The points, B,B, are moved over by the shoulders or irregularities on the said plate engaging with either of the studs or pins, ff^1, carried by the lever block, F, connected to the tongue cross bar. The points having been properly set in either position, the continued motion of the plate, E, causes one of the two projections, *e*, e^1, formed thereon, to enter a corresponding aperture provided in the cross bar, and thus lock them in the correct relation to the stock rails. The reciprocation of the aforesaid plate is also arranged to work the locking bar, R, by means of the bell crank lever, *r*, engaging with suitably located notches formed, therein as shown.

In both these arrangements it will be seen that the respective parts of the apparatus are so arranged and connected together as to be capable of being worked by one lever (usually) placed in the signal cabin.

At Fig. 174 is shown a further modification of this class of point locks, as suitably arranged for single line points. It will be seen that the points are similarly moved by the reciprocation of the notched plate, J, and the locking effected by a sword or plunger bolt, K, while they are so connected as to be operated by one lever as represented in the drawing referred to.

We avoid expressing any definite comparisons or opinions as to the degree of value, efficiency, or originality of any appliances, but for some of the most recent and latest arrangements, the last mentioned could hardly (*per se*) be believed to be about the best.

The use of a single lever and connections for actuating the entire apparatus is certainly a retrogressive step, and the time, we hope, is not far distant when the inspectors of the Board of Trade will express a decided objection to, if not prohibit, such contrivances.

And, in some arrangements, the result must be insignificantly cheaper, especially where much complex and irregular mechanism is resorted to, causing considerable wear and tear, besides being of very unsightly design.

Of course, in some instances, indirect and circuitous arrangements are purposely adopted or devised (at the sacrifice of the harmony of simplicity, utility, and design), in order to avoid infringements and legislative difficulties, or to create commercial patent rights, and in which direction, doubtless, much thought and ingenuity is displayed.

Several automatic switch devices have been contrived at different times for effecting a "continuous road," and amongst the most prominent of these is Mr. Price William's switch, which was put down on trial at Crewe some time ago, as will be doubtless remembered by many of our readers. However, as this apparatus has been so frequently illustrated and exhaustively described in earlier publications, and has not achieved any extensive adoption or recognition, we will not occupy our readers at present with any detailed notice thereon.

As electricity is rapidly developing as a means of power and control for various arrangements in connection with "out-door" signalling appliances, we will briefly direct attention to some recent ingenious contrivances by Mr. E. W. Stoney, C.E., of the Madras Railway, and T. K. Winter Telegraphic Superintendent of the same Indian railway company, and which have engrossed some passing interest in the railway world generally, if only for a matter of curiosity, as to what might be done in this direction.

The arrangements to which we refer are for effecting certain "improvements in actuating and locking railway points, and for further interlocking them with their relative signals."

According to this appliance, a transverse rocking spindle is caused to operate two cams or clamps, so as to wedge the tongues of the points against the stock rails, in a similar manner as already described with reference to other contrivances.

One or both of the cams may be arranged to slide without turning, so that the locking of the points may be independent of the accurate gauge of the lines.

The cam pieces are provided with projections, the one serving to hold the point rail tongue against the stock rail, and the other acting as a filling piece by being inserted between the other tongue and the stock rail.

The ordinary "treadle locking bar" is also arranged in suitable connection with the aforesaid device, so that when the cam moves round from one position to the other, it first raises the "bar," and then allows it to descend in either extreme position. In some cases "auxiliary treadle bars" are provided, so that a train approaching the points from the rear may cause them to be set correctly for either the main, branch, or siding lines, according as it may be desired to travel, and by which means a (technically termed) "continuous road" is obtained. For this purpose two treadles are usually provided, viz., one for the main and the other for the branch line, which carry suitably arranged inclines, so that when depressed they act on levers mounted on vertical axes in the middle of the way. The depression of the treadles causes the levers to turn about their centres, which motion is (by suitable connections) conveyed to the points, and thus cause them to assume the desired position.

When it is required to actuate points or signals from a considerable distance, it is preferable to employ hydraulic pressure, the desired action being obtained by pistons on weights, as will be easily understood.

In cases where the switches are worked by rods or wires carried to a distance, an arrangement is employed by which the rods or wires impart motion to a lever mounted on a vertical axis situated in the centre of the road.

This lever has projections formed upon it, which act upon corresponding inclines fixed on the point tongues, and by which agency they are forced into position.

The action of the point or signal lever is electrically controlled, by means of the lower end of the said lever being provided with a projection and a weighted catch, which holds it immovable, until the latter is withdrawn by an *electric impulse*, which acts upon an armature controlling a bolt-rod. This bolt-rod imparts motion to a finger piece, which acts upon a second light rod, jointed to the catch, by which means the latter is withdrawn from the before-mentioned projection on the lower end of the lever.

On closing or opening the electric current, this rod, connected with the catch, can be suitably controlled to engage or release the relative levers, when desired.

To do justice to the above apparatus, would require a voluminous description and array of drawings, for which at present we are unable to find space, so that we are now only enabled to briefly notice them, as probably forming an important basis for numerous new inventions. When we are more acquainted with the practical results of the same, we shall avail ourselves of an early opportunity of laying further details before our readers.

We have now laid before our readers almost every type of facing point lock of importance which have attained practical and established recognition, and received the most extensive adoption by the various railway companies in the United Kingdom. Of course, to exhaustively notice all such appliances (many of which doubtless possess features of originality and value, although not practically recognized or generally known) would necessitate more space than we could possibly afford to place at their disposal, and which if we were able to do, would be to many of us a very monotonous narration.

We will, therefore, pass on to briefly notice some other modified appliances bearing upon the subject at issue.

It is now deemed advisable or advantageous to provide (especially) at the junctions of single line railways additional means of locking the points, besides simply locking the lever and rods which shift them, and further to provide reliable means of indicating their position to the drivers of approaching trains, so that they may know for themselves whether they are proceeding with safety.

With this object in view, Messrs. Saxby and Farmer brought out about the middle of last year an arrangement for effecting the above purpose, and which is illustrated at Figs. 175 to 177 (inclusive).

Fig. 175, represents a plan of such an arrangement of junction points, in which A A, are the main or stock rails with point rails, B B, worked by a lever, C, in the ordinary and well-known manner.

D is a bolt for locking or securing the points in either position (*i.e.*, right for main or branch lines), and provided with the locking bar, R, both operated by the lever, F, which is, with lever, C, interlocked in the ordinary manner. The levers have additional connections, P^1, P^2, F^1, F^2, for working point-indicating apparatus as hereafter specified. The said indicators for day-light service are represented at Fig. 176, which is an elevation of an ordinary semaphore post with arms, A^1, A^2, for the "main line" and, B^1, B^2, for the "branch line" respectively, all four arms being arranged on the post, G, placed at any convenient position relative to the said points. For night service the coloured lights, A^3, B^3, serve respectively for the "main or branch lines," and which are visible upon being approached by either of the aforesaid lines. Describing one set of the connections, the rod, P^1, is attached to one arm, p^1, of a triple arm lever, the arm p^2 is connected by a rod, g, to one of the two jaws, r, pivotted on the rod, a, extending down the post from the arm, A^1. The rod, F^1, is likewise in communication with the one arm, f^1, another arm, f^2, of which is in connection by a rod, g^1, to the other of the two jaws, r^1, also pivotted on the rod, a. The two jaws, r, r^1, (represented to an enlarged scale in two positions at Figs. 177, 177*a*, and 177*b*) are constructed with a butt joint so that each portion can be turned apart independent of the other by a downward pull of one of the rods, g, g^1, but which portions, when in contact, will be caused by an upward motion of the same, to move as a single and independent lever round its fulcrum, so as to raise the rod, a, and so lower the arm, A^1. The arms, f^2, p^3, are also attached to a pair of jaws, which actuate a rod similar to that of a, in communication with the semaphore arm, B^1. In

a like manner, the connections, P^2, F^2, by means of similar levers, rods, and jaws (on the side of the post) work the arms, A^2, and B^2.

Now assuming the points set right for the "main line," but being unlocked are free to be moved, the state of affairs is indicated by the arm, A^2, being "lowered." If now, they should be suitably secured by the lever, F, which actuates the locking bolt, D, and treadle bar, E, then the rod, F^1, will be capable of operating the arms, f^1, f^2, and the rod, g^1 thereby moving the jaw, r^1, so as to lift the rod, *a*, and lower the arm, A, thus indicating that the points have been locked right for the "main line."

At the same time, however, arm, A^2, will be "raised" by the rod, F^2, controlled by the lever, F. On again unlocking the points and shifting them by means of the lever, C, to set them for the "branch line," the consequent action of rod, P^1, and arms, p^1, p^2, and rod, *g*, will release the butt of the jaw, *r*, from that of r^1, and so cause one of the pair to butt against its fellow or counterpart. By a similar series of operations on the other side of the post the arm, A^2, is "raised," and, B^2, "lowered," similarly indicating that the points have been moved for the "branch line" but not locked in such position.

Upon moving the lever, F, to lock them in such position the motion communicated through the rods, F^1, F^2, will cause the "raising" of B^2, and the "lowering" of B^1, thereby representing that they have been secured in each position.

Thus, it will be understood that the "system" may be extended according to requirements, one arm being provided for each road for showing that the points have been correctly moved, and a second to further indicate that they have been secured in such position.

We will now proceed to consider a very ingenious and effectual method of extending the now well-recognized security of the "interlocking system" to "outlying points," which are placed too far from a station signal box to be worked and interlocked with the signals in the usual manner.

About 1875 Mr. J. E. Annett, the signal superintendent of the London and Brighton Railway, was engaged in endeavouring to arrange some effectual device for locking a pair of "outlying points" at a sand-pit siding close to a tunnel, and about a mile from Dorking station, which, owing to the distance, presented considerable difficulties. Counterweighted wires or rods for actuating a locking bolt in the usual manner were obviously unsafe at such a distance, and where the points were out of sight, for the rods were very liable to buckle, whilst wires failed to give the required control if anything should accidentally get interposed between the tongues of the points.

Mr. Annett thoroughly appreciated the difficulties and lack of safety in such arrangements, and upon which he did not fail to express his opinion, although temporarily at a loss to see how to overcome them.

Mr. Williams, the traffic superintendent of the line thoroughly acquiesed that little dependence could be placed in the application of the usual contrivances, considering the distance and unfavourable position of the points, and accordingly expressed a desire that some analogous device to that of the "staff system" should be contrived.

Mr. Annett very soon found his resources equal to the emergencies, and before many weeks had elapsed, proceeded to protect by Letters Patent (in Oct., 1875) the very ingenious piece of apparatus, which we shall now describe and which up to the present date still remains unsurpassed for simplicity or efficiency.

According to this arrangement the points are connected to a single lever located by the side of the metals in their immediate vicinity. This is fitted with a lock of peculiar construction, to be hereafter explained, a duplicate of which being also annexed to the relative signal levers in the station signal box. One key only of special design is provided, and the use of which is so arranged that after being employed in either of the locks, it cannot be extracted therefrom without first securing the points or signals in their proper and safe position.

Thus the operator cannot part with the key for use at the outlying points, without first having the conflicting signals locked at "danger," and so placed beyond his control until the key is returned. In this manner the "key" is made master of the whole system, similarly to a "train staff" employed on single line railways, for as it cannot be in two different places at the same time, no operation of the station signals can be effected at variance to the position of the "outlying points."

Fig. 178, Plate CXXXVII., represents a plan of a siding with its points, and illustrating Mr. Annett's arrangement for securely locking them in proper positions relatively to the signals.

Fig. 179 shows a detached elevation of the lower portion of a signal post with apparatus for locking the signal in its proper altitude or position. A A are the stock or main rails of an ordinary siding, communicating with a main line by the usual point rails, B B, represented in the drawing as secured in their proper position for the "main line" by the point lock, C, to be described farther on. The points are operated by the usual mechanism common to such appliances, as before explained. A similar duplicate lock, C^1, is also applied to the signal rod, D, as indicated at Fig. 179 for securing it at "danger" when the points are being used. The bars, E E^1, forming part of the connection between the point lever, F, and the points, B B, or that between the signal lever, G, and semaphore, has a transverse recess into which the termination of the bolt engages when locked, and from which it is withdrawn when unlocked.

Fig. 180 is a detail plan of the lock detached, with a portion of the sliding bar, E, therein. Fig. 181 is a similar representation, showing the apparatus unlocked, with the

key immovably detained, the cover plate of the lock being removed, for the purpose of more clearly explaining the internal construction. Fig. 182 is a like view, showing the apparatus in its locked condition, and which allows the key to be withdrawn. Fig. 183 shows a longitudinal section taken on the line, X X (Fig. 181) of the lock when open with the aforesaid key imprisoned therein; while Fig. 184 represents a detached plan and side elevation of the sliding catch plate and Fig 185 a side and end view respectively of the key to be employed in connection therewith. By preference, the key is made of such design that it will only fit or suit one lock for a certain pair of points and its relative signals on the same line, so that its office cannot be misappropriated by negligence or ignorance. The catch plate, *k*, is arranged above or in front of the locking bolt, *l*, and is controlled in its proper position by the sides of the case, *m*, and the projections, *a a*, provided on the under side of the cover plate, *n*. Recesses, *b*, b^1, are formed in the catch plate for the reception of the "tumblers," *c*, of the lock, similar notches, *d*, being arranged on the bolt, *l*.

The aperture, *e*, in the bolt (represented by the dotted outline at Figs. 181 and 182) is for the reception of the "bit," *f*, of the key, which moves the bolt, whilst the "tumblers" are raised by the "bit," *g*. An additional "bit," *h*, is provided, which extends in nearly the reverse direction to that of *f* and *g*, enters and moves (by the opening, *i*, in the catch plate) the said plate in the opposite direction to the bolt. Now, upon unlocking or withdrawing the bolt from the notched bar, E, the solid portion of the catch plate will be caused to come over in front of the "bit," *f*, so as to detain the key.

The sliding bar, E, works in a slot or aperture, arranged across the lock, and when moved to the attitude for closing the points, or putting "on" the signal to "danger," its notch is made to coincide with the position of the end of the bolt, *l*, and so enabling it to be secured upon turning the key. The aforesaid bar is constructed so as to completely occupy the slot, within which it works, so that as long as the solid portion thereof is opposite the bolt, all motion of the latter is entirely prevented, and consequently the key is detained in the locking apparatus, and not until the notch in the bar is moved to coincide with the plane of the action of the bolt, can such conditions be altered.

A similar immovability of the apparatus and the incapability of removing the key, until the points are properly moved and secured, exists in both locks, so that the key cannot be withdrawn from the signal post or frame for unlocking the points until the signal has been set to its "danger" attitude. While, conversely, the points having been *un*locked the key cannot be withdrawn from this portion of the apparatus, until the points have been properly placed and secured.

At Fig. 186 is given a perspective illustration of an "outlying siding" connected by a cross-over road with the "main down line," both ends of which diagonal road are suitably attached to the single lever, shown by the side of the metals, in the foreground, and fitted with one of Mr. Annett's patent safety locks, in which the key is shown projecting. An exact duplicate lock is provided on the frame of the relative signal levers within the station box, seen in the distance round the curve, and operated by the same key in the manner already explained. Fig. 187 shows the manner in which the lock within the distant cabin is suitably applied to the frame to control the signal lever, while Fig. 188 shows the key itself, which may, if desired, be used additionally as a "train staff." For example, in the case of isolated sidings on single lines, the key may be used as a "staff," so that the points cannot be used by a train not in possession of it, and which, on the other hand, if carried and employed cannot be removed without leaving the point properly locked.

It may be useful to state by way of conclusion that this efficacious piece of apparatus, which is very extensively used, is now manufactured by Messrs. Saxby and Farmer, who have purchased Mr. Annett's patent.

In the combined views given at Fig. 189, is represented a "system" of controlling points from signal cabins in cases where the former are placed too far away from the boxes to be worked from interlocking frames, and is the invention of Messrs. Tweedy & Co., Signal Engineers, of Carlisle. For this purpose a dwarf frame and an indicator of special construction and arrangement are placed within the signal cabin. A lever is provided so as to lock in the cabin frame, and also another lever to actuate the indicating apparatus. The dwarf frame quadrant is provided with three notches, so that when the lever is in its normal position, as represented in the first view, the indicator, B, in the cabin, stands at "line clear." The interlocking is so arranged in the dwarf frame, that the lever, *A*, can be pulled over to the second notch, when it is desired to signify to the main cabin that the points are required, and by which action the indicator is caused to revolve through the intervention of the rod, C, and the rack and pinion motion, D.

When the indicator shows to the operator in the cabin "siding points wanted," the lever, A, cannot be pulled over past the second notch until the lever placed in the main cabin is first operated, and which locks the "up and down" main line signals. The indicator lever can then be pulled into the back notch, so as to release the point lever required, thereby causing the indicator to revolve so as to exhibit on the dial, the words "main line fouled" and at the same time back locks the lever in main cabin. In this manner all the "main line signals" are properly secured at "danger," when the conflicting points located at a distance are being used. When the point lever in the dwarf frame is pulled over, it locks the indicator lever in the back notch, and cannot be again moved until the points are once more right for the "main line."

The height of the cabin indicator is about 3 ft. from the floor, and consists of two sheet iron circular cases, the outer one being fixed on a pedestal, while the inner one, serving as the dial with the suitable words thereon, is secured to and revolves with the perpendicular shaft a spindle in connection with the rack and pinion gear, D. It will, therefore, be understood that as the lever, A, is pulled to the second or third notch a certain notice or signal is caused to appear in the open part of the relative indicator.

The above arrangements have been favourably commented upon by the Board of Trade and engineers on lines where they are fitted, and this precautionary apparatus is especially useful in cases where the guards of goods trains have to manipulate the points, as it obviously prevents any negligent blunder which might be likely to cause an accident. For unless the points are right (or returned) for the "main line," and the indicator lever in the front notch, and likewise that of he controlling lever in the main cabin similarly put forward the signals for the "main line" cannot be used.

(*To be continued.*)

LIGHT RAILWAYS.

STEAM CARRIAGE OF THE FRENCH STATE RAILWAYS.

TWO of these carriages, illustrated at Plates CXXXVIII. and CXXXIX., were built in 1879 from the designs of the French State Railways. They are constructed with compartments for three classes of passengers, and in addition have a compartment for the mail service. It will be seen, from the longitudinal section, Plate CXXXVIII., that the boiler has an internal fire-box, the heated gases passing over the fire-bridge and returning through the boiler by means of the tubes to the chimney, which is at the same end of the boiler as the fire-door. All the working parts are between the wheels, the cylinders being attached to central beam, which is united to the two transverse end-beams of the frame. The levers for controlling the slide valves and brake are placed on the right hand side of the boiler directly beneath the hand of the driver, in a direction parallel to the road. The separating wall between the baggage and engine compartments is quite solid, the depth of the panels (4 in.) forming its thickness. The form of the body and the structure of the frame of the carriage have been taken from the two-storied carriages of the Vendée type.

The frame, which is entirely of metal, is made elliptical, as in the carriages of the Vidard type. It has been designed so that the parts may yield readily to the gradually increasing force of the motor properly so-called. The engine and frame of the carriages were constructed by the Cie. de Fives, Lille. The body was made by M. Chevalier.

These carriages commenced running in 1880 by a "decree of the 20th May, 1880, authorizing by right of trial the running of steam carriages." The number of men in charge can, in the case of a single carriage, be reduced to a driver and a conductor to attend to the brake. We may add that since the above date two agreements, between the Cie. des Chemins de Fer de l'Est and the Minister of Public Works have been signed for working branch lines, and in which the following clause appears at the end of the first article :

"The Cie de l'Est engages to alter the method of working this line, within a period of six months, in accordance with the conditions of the Decree, May 20th, 1880, which authorizes the running of steam carriages carrying their own motor, and of light locomotives, without tenders, drawing one or more carriages."

We give below the principal dimensions of these carriages.

Diameter of cylinders...	8.25	inches.
Stroke of pistons	14.15	,,
Diameter of driving wheels	56	,,
Do. carrying wheels...	38	,,
Pressure in boiler	20	lbs.
Number of tubes	51	
Exterior diameter of tubes	2.16	inches.
Thickness of tubes	.1	,,
Length of tubes (between tube plates) ...	82.5	,,
Heating surface { tubes	189	sq. ft.
Heating surface { direct	56.25	,,
Heating surface { total	245.25	,,
Grate area	5.5	,,
Carrying capacity { water	374	gals.
Carrying capacity { fuel	1320	lbs.
Weight of motor (boiler, engine and frame)...	14.41	tons.
Total weight of carriage and engine... ...	19.5	,,
Maximum weight of carriage when running...	27.25	,,
Weight on driving-axle (approx.)	11.76	,,
Weight on each of the other axles (approx.)...	7.85	,,
Tractive force (.65 of the effective pressure)...	1458.6	lbs.
Adhesive force (.14 of weight, mean approx.)...	33.88	,,

CARRIAGE.

No. of places below	1st class	1 coupé ...	4	places.
No. of places below	2nd class	1 compartment	10	,,
No. of places below	2nd class	1 coupé-porte	4	,,
No. of places above			24	,,
Total			42	,,

THE PROJECTION AND CONSTRUCTION OF RAILWAYS—COMMERCIALLY AND PRACTICALLY CONSIDERED.

(*Continued from page* 10.)

WE now come to the actual designing of the works *necessary* for the completion of the railway, and as a study of successful works, that is to say, of works that have not yet failed, is open to every student and pupil (so far as the engineers and contractors will permit it), we purpose, in the first instance, to point out to the young engineer what he should avoid doing. In order to carry out this course it will be necessary to indicate a few of the difficulties by which the tyro *fresh from college* is beset. He is given the longitudinal and cross sections, and told to draw a bridge at, say, 5 miles 54 chains. Then follows a dialogue somewhat of this sort, probably after the "instructed one" has looked for an hour or two through the cross sections :—"But there isn't a cross section at 5 miles 54 chains." "Well I'm busy now, look at the contract drawing, and get an idea from that, and here's the plan." The youth will begin to feel nervous and think that perhaps he is dull and does not know how to apply the knowledge he has had so assiduously driven into him by his academical preceptors. (We may, perhaps, be here allowed a parenthetical digression to state that a young gentleman of fair abilities once came under our notice, who, on leaving college, was a really brilliant geometrician. After three years pupilage he admitted he had lost this high analytical power; who, we ask, *could forget* Euclid had he once understood his writings.)

But to return to our tyro and his instructor, the former has found out that the bridge to be "drawn" is not at the same peg as that illustrated by the contract drawing, and, moreover, it may, to suit some purpose, be on the skew, so that even if there were a cross section at the place where the bridge *is to be* constructed, such cross section would give no idea of the ground. "Well, compile a section ; I am going now, and will see you in the morning; by the way, have the compiled section ready."

Now, without following the tedious hours passed by the really earnest aspirant to engineering honours (?) we will point out that it is physically impossible to compile a section, as impossible as it is (on any but, dead, flat ground) to get correct earthwork quantities from Bidder's tables.

The data given from which to compile a section are usually these, first, the longitudinal section; secondly, the cross sections; now even if the line be straight it is evident no section that is compiled can take cognizance of intervening irregularities of surface; if the line be on a curve the inaccuracies will probably be greater, but in any case the result is a mere guess, wherefore we advise both pupils (whose pecuniary position leads them to take to civil engineering merely because *they think* it is *a profession* and not a trade, and those who without pupilage are striving to work their way up) to object to make drawings of any sort based upon that *ignis fatuus*, a compiled section, for nothing but dissatisfaction can result, and only too often the fault is laid to the assistant, when it is really the principal who is to blame.

Often enough an engineer may say to his assistant, "See what you can do with this, it is wanted at once ; if it does not quite fit we can alter it on the ground ;" then, his mind occupied with other matters, he forgets the exact nature of his instructions in this particular case, the drawing passes to the contractor who pushes on the work until it becomes impracticable to pursue it further ; something has to be pulled down or patched up, and the whole work is a botch and a disgrace; then the draughtsman is blamed, as it is necessary to throw the blame upon some one, and *it is not to be borne that blame shall be cast upon those in authority*.

We will now speak about the duties and difficulties of the "draughtsman" in a railway engineer's office.

We assume the draughtsman to act in that capacity simply —the word simply has a most extensive meaning here, first, as to his qualifications, he must be a good *practical* mathematician ; not a man who, when asked a question, must grope through Molesworth or Hurst for a rule or formula, but one who, being acquainted with *general principles*, can deal with any variety of case that may arise, and that promptly. It may be taken as a general rule that a man of many note-books is an incompetent man, even when he understands the note-books which have to serve him in lieu of brain and experience, and this is not always the case; though of course it is rare to find a man so densely dull, if he has had any education at all beyond the three R's, that he cannot comprehend his "crutches," the note books, but must needs ask others to teach him how to rest on them. Next, the draughtsman must have a thorough knowledge of the strength and qualities of materials practically, and not only that but practical experience in the actual construction of works, stone, brick, timber, and iron, in order that he may know what can be made and what cannot, so that he may fearlessly hold his own against petty contractors and sub-contractors.

The draughtsman must, moreover, have somewhat of patience, he must bear the assumption of authority by intellectual inferiors who take the credit for his work, although he knows

in his own mind that he is really the *deus ex machina*, the help at a dead lift, to those who know what they want done but know not how to do it.

In no case is this thoroughly practical knowledge more urgently required than in the hasty preparation of estimates, where it certainly does not answer to adopt the old mechanic's estimate method of "making a shrewd guess and dividing by two," and more especially difficult are rough or approximate estimates of iron structures if they happen to be at all out of the ordinary run, in which case some aptitude at mental calculation is necessary, though of course this is no particular point, as it will come naturally to any man who, *having his living to earn*, takes to the business of engineering from a liking for it, and so makes it, as it were, part and parcel of himself.

The draughtsman has often a very great difficulty to contend with in not seeing the ground upon which the works are to be erected; he has to trust entirely to plans and sections furnished him, and such vague verbal information as the surveyors and resident engineers may choose to afford him, and all this put together will not give a tithe of the assistance that personal observation on the spot will supply, and of the actual experiences arising during the progress of the earthworks, he will probably learn nothing as that is out of his immediate department, and therefore not included in his instructions; this difficulty may, however, to a great extent be got over, if the draughtsman have his wits about him, for what he is not told in the office he can learn outside it, and be kept perfectly informed of all that is going on, so long as he keeps such information for his own use, and remains apparently ignorant of all, except that which he gathers from those who officially direct him.

Before leaving the question of the draughtsman's relations with their employers, there is one point we especially wish to urge, it is this, that they should never (without the express permission of their principals) take any copies of calculations, drawings, or other records of works that may pass through their hands in the course of business, their time is paid for, and all they do in office hours is the property of their masters, and to take records of work done in that time for future use, is morally dishonest, such maturing of experience as may in some cases occur, accrues naturally, but no effort to benefit by the work of the employers should be made.

Where the employers give permission to their paid assistants to take notes, things are on a different footing, and it is a certain fact that it is to the advantage of the former to do so, for a greater amount of work is got out of a man who works cheerfully, feeling that he is not only working for a master but also for a friend, than from one under constant espionage on the silent system, who, we should imagine, must find his energies cramped, however willing he may be, by the feeling that he is condemned to so many hours hard labour per diem.

We will now return to the actual question of designing and setting out the works; take as a first case a brick bridge under the railway, and let it be an accommodation bridge, that is to say, one to give access from field to field. The span will be settled by agreement with the landowners, through whose land the line passes; in nearly all cases these bridges may be built on the square, that is, at right angles to the direction of the line of rail, or, if the line be on a curve at right angles to a straight line tangent to the curve at a point corresponding to the centre of the proposed bridge.

We assume in this case that the railway is sufficiently high to put in an arched bridge without having to lower the natural surface of the ground. If the ground surface is horizontal in all directions, the matter is very simple; the correct form and thickness of arch and abutments are readily determined, and then it only becomes a question whether the wing walls which uphold the bank shall be curved say in quadrants, or straight, but in speaking of straight wing walls we must point out that the wing walls must never be built *absolutely straight* with the settlement of the brickwork or masonry, as the case may be there will always be a tendency in straight walls to bulge, and this must be obviated by building the wing walls slightly concave on the face, the amount of concavity will depend upon the nature of the work, but as a general rule it may be taken, that regarding the face line of the wall as an arc in plan, the versed sine of that arc should be six inches per twenty feet of length where good sound material and workmanship is employed, and one foot per twenty feet where slovenly work is likely to pass.

The wing walls should be built with plumb backs and battered faces, the batter varying from 1 in 8 to 1 in 6 as may be most convenient, by 1 in 8 we mean that for every foot rise (vertically) of the wall the face should fall back $1\frac{1}{2}$ in., and the coursing or bed joints of the stones or bricks should be made *at right angles to the face of the wall.* Where the (approximately) straight walls are used they should not be run parallel to the centre line of the road passing under the bridge, but should diverge from the face of the bridge at an angle of somewhere about 45 degrees, they need not be carried out to the extreme toe of the bank, but may terminate in a pillar around which the bank will fall following its general slope, but the pillar must not be far enough back in the bank to allow the earth falling round it to encroach upon the width of the approaches to the bridge.

The backs of the abutments and wing walls should be dry lined about 9 in. thick, with broken stone packed by hand as the work rises, this for the purpose of drainage; the top of the wall will follow the slope of the bank, and above that have a stone coping terminating at the upper end against the the face or pilaster of the bridge, and at the lower end in the square cap of the terminal pillar. The coping should project 3 or 4 in. beyond the face of the wall, and be throated beneath so that rain may not stream from it down the face of the wall.

The parapets of the bridge itself should for safety in all cases be made 4 ft. 6 in. above rail level.

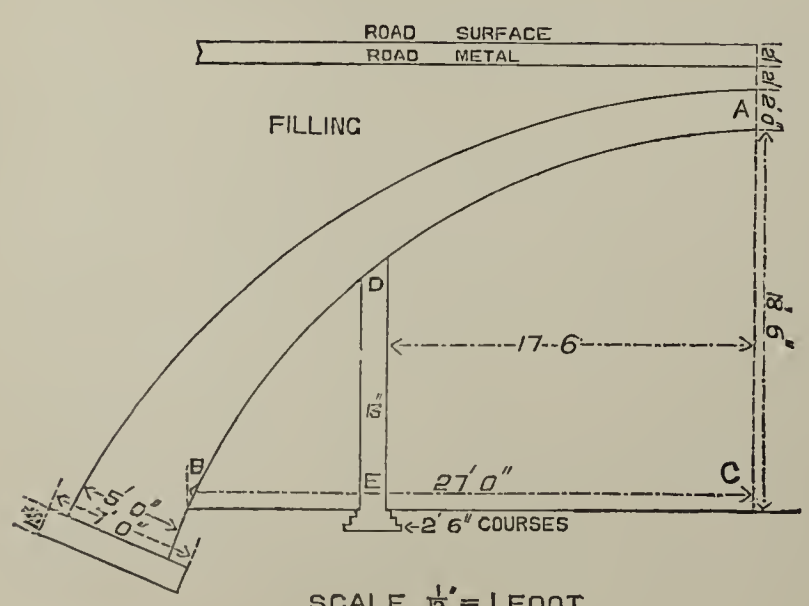
The form of the arch will be determined upon the ordinary principles of static equilibrium, and we shall *generally* find that if a circular segment, of which the versed sine is one-fourth of the chord, be used, the theoretical line of thrust will be within the middle third of the thickness of the arch. When the chord or span exceeds 20 feet, no brick arch should be made less than 2 ft. thick, to carry a railway, of course, the crown of the arch should be kept 2 ft. below rail level.

In dealing with the abutments as to thickness, the question must be viewed in two different ways; first, regarding the abutment as an abutment to the arch; second, regarding the abutment as a retaining wall to the bank of earth behind it; in both cases considering the utility of counterforts and of pocketed abutments.

Considering the abutment as acting as an abutment to the arch, no allowance must be made for any support from the earth behind the abutment, and that for several reasons, of which the following are the principal:—(1) The instructions embodied in the specification that earth shall not be tipped against an abutment, but placed in layers one foot thick, of which the surfaces shall incline *away* from the wall or abutment, each layer being well punned before the succeeding layer is thrown upon it. (2) However soundly the earth may be packed, yet some subsidence must occur, and with such subsidence all support to the abutment from the earth behind it is lost. (3) The action of the traffic on the banks is to spread them laterally, not longitudinally—this has been shown by an experience extending over fifty years. Longitudinal *slips* occur, but those are always due to negligence in not cross-benching the ground along which the centre line of the railway passes. Hence the abutments must be made sufficiently stable to resist the *whole* thrust of the arch.

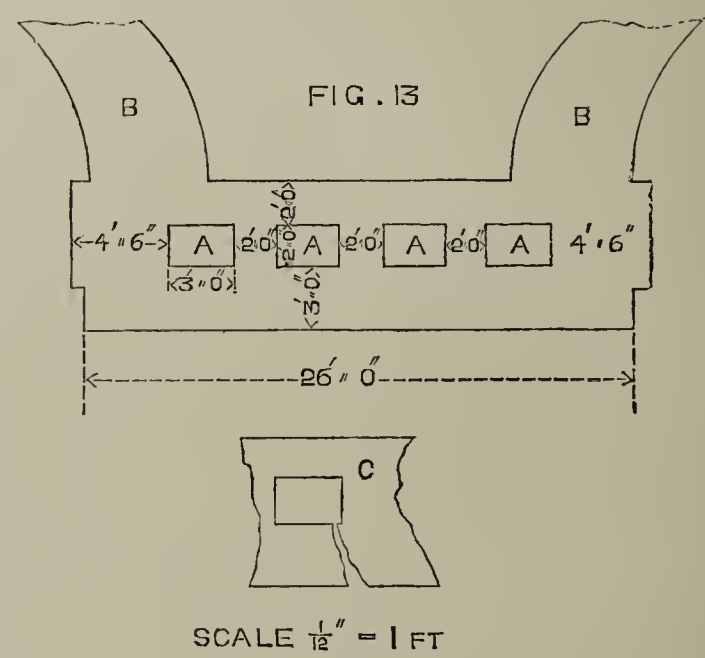
In some instances it occurs that the ground itself is too loose to afford what we may roughly call sufficient hold for the abutments, in which case it is best to spring the arch from the foundation itself, when a solid foundation is found; and build up a false abutment on face wall, as shown in Fig. 12.

FIG. 12



A B is a semi-arch designed to carry the railway over a road 35 ft. wide, A C being the centre line, the face wall is shown at D E. Such structures are undoubtedly more reliable than those arches that abut upon a pier of masonry, for, having their surfaces of support on the solid rock, or upon shale equivalent to solid rock, no vibration can disturb the ratio of rise to span.

We must now regard the abutments of an arched bridge as retaining walls to the banks behind them, and in this case it is safest not to make any allowance for the thrust of the arch. One of the most usual blunders made by young, and even by old engineers, is to construct abutments with counterforts behind them, for it is evident that these counterforts are of very little use so far as stability is concerned in supporting the bank pressing upon such abutments.



Instead of using counterforts, the writer of this article has always preferred to use pocketed abutments, as shown in Fig. 13. The pockets are shown at A, the wing walls springing from the abutments at B. But in no case should these pockets be filled with concrete, as in the setting of such concrete there is a danger of splitting the corners of the masonry, as shown at C, Fig. 13. The pockets or voids must be covered by flagstones, which should be six inches thick, and extend over the voids six inches in all directions.

In constructions of this nature, it must always be borne in mind that no foundations must be laid until a solid bottom is found, and if the soil is of such a character that no solid bottom can be found, other means must be used to secure the stability of the structure to be superposed upon such ground.

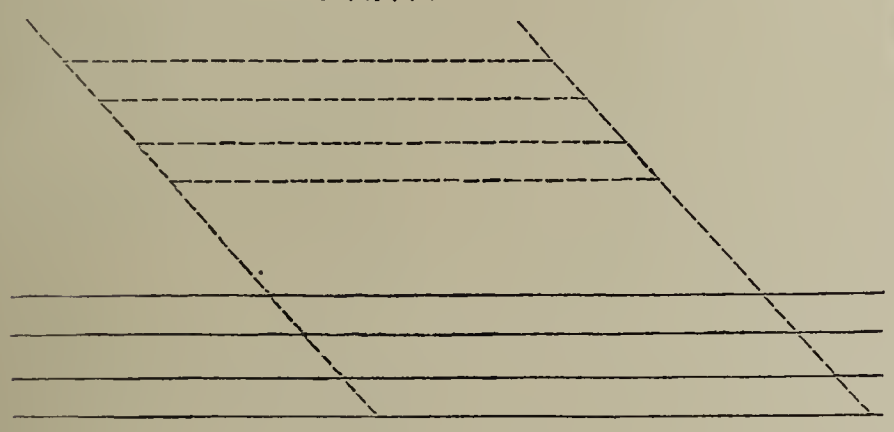
We will give an instance of this in the case of the Parrett Bridge, at Bridgewater, constructed under the direction of the writer of these articles, for the Wednesbury Patent Shaft and Axletree Works. The Parrett Bridge is a rolling bridge, it being necessary to open it to permit the traffic on the River Parrett to pass, and the quays would not allow sufficient space for a swing bridge, therefore it was absolutely necessary to so design the bridge that it could be drawn back inshore to allow vessels to pass.

The original design was one of the most absurd that has

ever been presented to a contractor, the pitch of the rivets was (so far as our memory serves us) 4·3185.

It was found necessary to arrange a portion of the permanent way so that it could be laterally drawn away to make room for the rolling back of the bridge. We must mention that at that time both broad and narrow gauge was in use upon the railway. In order to actuate the bridge, it was necessary to have a firm hold, and at the same time we had to observe economy, and for that reason, the foundation of the tangent screw and worm-wheel was made by fixing the casting carrying the worm-wheel upon two H irons, at the end of which were two iron plates, similar to those attached to paddle-wheels. These kept the base plate of the worm-wheel steady, whichever way the tangent screw was working, and this arrangement has proved satisfactory after twelve years work.

FIG. 14



SCALE 32 FT = 1 IN

In dealing with bridges over the railway, we have other matters to consider; the first and most important is the headway, for with such hasty work as we have lately seen, a slight subsidence of a brick arch might wreck a train, and the specifications issued seemed so utterly ignored by contractors that they are no guarantee for the stability of the structures erected.

Where headway is short we get over the difficulty by putting in iron girders instead of brick arches, but it must be remembered that these girders are to be of wrought iron, otherwise we may get cast iron girders made of metal utterly unreliable; and in this connection we will point out a matter that came under our notice some years back, when the contract for the iron work having been already late, an extra half-crown per ton was permitted by the directors to be paid to the contractors for the iron work, although, judging from the quality of the iron, they were paid well enough at the original price.

In the construction of iron bridges over the line of railway care should be taken by the resident engineer to ascertain whether any gas or water pipes are to be carried through the structure, for it is exceedingly awkward subsequently to carry such pipes through, and even if we can it may lead to an extra load that brings the tensile strain above that allowed by the Board of Trade.

In constructing bridges *under* the railway it is better, if possible, so to arrange the work that we can get one girder under each line of rail; for by so doing we save the expense of cross girders, and the brackets necessary to carry the railing outside the lines is only about one quarter of the cost of the cross girders, and, in addition to that, we save the distributing girder, which is necessary in almost every case in the North of England, to give sufficient rigidity to the bridges carrying a double line of railway upon two side girders.

One of the stiffest platforms constructed in the North of England is, to quote from General Hutchinson, "that which carries the Laisterdyke branch line to Shipley over the Leeds and Liverpool Canal," and in that bridge there are cross girders 34 ft. long, but by an arrangement of a distributing girder that runs through the floor of the bridge beneath the plates it is so stiffened that on General Hutchinson's inspection after testing it in every way, he expressed his opinion that it was the stiffest platform he had ever tested; and it must be borne in mind that there is a junction on this bridge, as the junction referred to connects the Great Northern Railway with the Midland Railway at their Shipley station; and the signal box of the Midland Railway works with a goose-neck slot into the signal box controlling the Great Northern signals.

In this case there was one difficulty—the Company were so tied for head room, in order to give sufficient way for boats passing along the canal, that there was scarcely half an inch to spare, and at the same time the total span of girders was somewhat large, the largest being 108 ft. and weighing 40 tons when constructed.

We should not advise any young engineer to include cast iron girders in his designs for bridges. Since Mallett's patent has expired for buckle plates, those plates can be had at the ordinary price of flat iron plates, and, therefore, it is better to specify them than wrought iron flat plates or cast iron floor plates, for although the sub-contractors put, as a rule, a pound a ton upon the price for buckling plates, the resident engineer has only himself to thank for putting up with such imposture. Cast iron girders made of sound metal can be relied upon, but they must be carefully tested before they are placed in position, and should in every case be bedded upon felt, so that no sudden jar may cause them to crack; these girders should be made of grey iron, and in no case should they be placed *in situ* unless one has been broken to show the deflection that occurs before fracture. From every cast there should be three bars cast, of which the size will be 3 ft. 6 in. by 2 in. deep by 1 in. wide, and one of these bars should be supported upon bearings 3 ft. apart, the bar being placed on edge, and all castings should be rejected in case one of these bars breaks with a load of 28 cwt. in the centre.

All columns that may be necessary to support bridges should also be tested, and in a general way the following test should be used: A cast iron column, 12 ft. long, bolted by its base to a wall should not deflect more than one quarter of an inch under a load of 1 ton applied at the end.

(*To be continued.*)

(*Continued from page* 21.)

TABLE I.—(*continued.*)

1	2	3	4	5	6	7	8	9	10	11	12	13
No. of Piece.	Makers.	Application.	Year made.	Modulus of Elasticity. Kg per sq. mm.	Limit of Elasticity. Kg. per sq. cm.	Breaking strength. Kg. per sq. cm.	Contraction of Area per cent.	Elongation in 25 cm. (10 in.) per cent.	Analysis. Carbon per cent.	Sulphur per cent.	Phosph. per cent.	Remarks.
57a	Petin Gaudet & Co.	Wagon Tyre	1869	1 964 000	710	3050	5	—	0.31			Very coarse grain, with bad cracks; wide cracks, lengthwise and crosswise, on outside, one opened widely during test, but it broke elsewhere.
57b	ditto	ditto	1869	2 117 000	1660	3670	9	4.1	0.32			Three-fourths coarse uniform grain, rest dirty, porous, cracked, clearly cinder. Outside cracked, even where the fracture was good.
				C.—RAILS (Round Test Pieces).								
54a	Anina Iron and Steel Works,	Head of Steel Rail		2 278 000	1930	5040	15	—	0.29			Coarse grain.
54b	ditto	ditto		2 274 000	2160	5240	31	18.8	0.22			Very coarse grain, with very dirty honeycomb, outside much cracked.
17a	Bochum Mine and Steel Co., Bochum.	Rail	1873	2 065 000 1 969 000	1250 3030	5010	6	—	0.24			Very coarse grain, with fine flaw at one side; transverse cracks all the way along this side. Two limits of elasticity.
17b	ditto	ditto	1873	2 138 000	1930	5400	9	7.7	0.29			Very coarse grain, flaw at edge, that side much cracked outside.
				D.—BAR, TOOL, AND SPRING STEEL (Flat Test Pieces, unless otherwise stated).								
51a	Konig & Reunert, Annen Cast Steel Works	Flyer Bar	1873	—	—	6620	51	16.2	0.39	0.03	0.145	Very fine grain, angular fracture, much arsenic. Round piece.
51b	ditto	ditto	1873	—	—	6620	41 48 at the smallest section	15.6	0.42			Similar, somewhat uneven. Round piece.
36a	Asbeck, Osthaus, Eicken & Co., Hagen.	Locomotive Spring Bearing	1877	2 200 000	3385	8520	25	15.0	0 79			Very fine grain. This and the next 7 were from steel which gave very good results.
36b	ditto	ditto	1877	2 228 000	3130	8520	14	12.2	0.72			Very fine grain, small flaw at one corner.
32a	Bochum Mine and Steel Co., Bochum.	ditto	1877	2 224 000	4640	8080	35	16.7	0.43	0.035	0.0701	Very fine grain, fibrous in middle, silica 0.77.
32b	ditto	ditto	1877	2 270 000	3720	8330	33	17.1	0.42			Same as last.
33a	ditto	Wagon Spring with rib	1877	2 174 000	3700	7540	29	17.3	0.33			Ditto.
33b	ditto	ditto	1877	2 196 000	3830	7660	19	14.2	0.35			Fine grain, somewhat irregular, much clearer than before.
43a	ditto	ditto	1876	—	—	7380	6	4.1	0.62			Very fine uniform grain.
43b	ditto	ditto	1876	—	—	7670	—	—	0.32			As the last. Broke within holder.
10a	Böhler, Bros. & Co., Vienna.	Tool	1876	2 253 000	4180	8960	—	—	1.56			Fine grain, radiating from one point at edge. Broke at nick-mark for instrument. Round piece.
10b	ditto	ditto	1876	—	—	9830	9	—	1.53			Fracture as last. These two were excellent steel for turning hard tyres, &c. Round piece.
18a	Eibiswald Cast Steel.	ditto		2 259 000	above 5130 below 5960	8520	5		1.52			Very fine grain. Broke at nick. Round piece.
18b	ditto	ditto		2 292 000	5280	9010	5		1.56			Same as last.
56a	ditto	Base of Machine		2 284 000	4600	8980	1.5		1.55			Manganese steel. Broke at nick. Round piece.
56b	ditto	ditto		—	—	9010	2.5		1.84			Same as last.
34a	Huth, Hagen.	Locomotive Spring	1877	2 158 000	4480	8300	16	14.1	0.70			Uniform fine grain, with small flaw. Quality found very good.
34b	ditto	ditto	1877	2 304 000	3950	8520	12	11.6	0.71			Same as last.

1	2	3	4	5	6	7	8	9	10	11	12	13
No. of Piece.	Makers.	Application.	Year made.	Modulus of Elasticity. Kg. per sq. mm.	Limit of Elasticity. Kg. per sq. cm.	Breaking strength Kg. per sq. cm.	Contraction of Area per cent.	Elongation in 25 cm. (10 in.) per cent.	Analysis. Carbon per cent.	Sulphur per cent.	Phosph. per cent.	Remarks.
35a	Huth, Hagen	Wagon Spring with Rib	1877	2 218 000	3390	7040	13	11.0	0.53		0.0652	Good quality. Very fine grain. Broke through deeply stamped letter.
35b	ditto	ditto	1877	2 241 000	3130	6910	15	11.2	0.52			Good quality. Very fine grain.
11a	Fr. Krupp, Essen	Loco. Wagon Springs	1876	2 263 000	3090	7560	2	—	0.81			Good quality. Medium grain, showing a transverse crack through whole width.
11b	ditto	ditto	1876	2 275 000	3170	7760	—	2.8	0.87			Good quality. Very fine grain, irregular.
30a	ditto	Locomotive Springs	1877	2 174 000	2800	—	—	—	0.73			Good quality. Broke through deeply stamped letter.
30b	ditto	ditto	1877	2 230 000	2820	7630	19	14.6	0.74			Good quality. Fine grain, with small flaws.
31a	ditto	Wagon Spring with Rib.	1877	2 253 000	3600	8600	12	12.5	0.64			Good quality. Fine uniform grain.
31b	ditto	ditto	1877	2 234 000	3200	8820	15	12.1	0.63			Ditto ditto
44a	ditto	Spring with Rib.	1877	not taken	not taken	6340	22	19.7	0.14			Experience satisfactory. Fine grain, with small flaw at one corner.
44b	ditto	ditto	1877	ditto	ditto	6070	20	18.2	0.27			

APPENDIX II.

RESULTS OF EXPERIMENTS ON STRENGTH.

Carried out for the German Railway Union as a ground-work for the Classification of Rolled Iron, Ingot Iron, Forged Iron, and Puddled Steel, by Professor Bauschinger, at the Technical High School, Munich.

TEST PIECES FOR CLASSIFICATION OF IRON AND STEEL.

1	2	3	4	5	6	7	8	9	10	11	12	13
No. of Piece.	Makers.	Application.	Year made.	Modulus of Elasticity. Kg. per sq. mm.	Limit of Elasticity. Kg. per sq. cm.	Breaking strength. Kg. per sq. cm.	Contraction of Area per cent.	Elongation in 25 cm. (10 in.) per cent.	Analysis. Carbon per cent.	Sulphur per cent.	Phospb. per cent.	Remarks.
I. ROLLED IRON. A.—AXLES (Round Test Pieces).												
146a	Reschitza Iron & Steel Wks.	Carriage Axle	—	1 932 000	937	3350	54	—				Fibrous uniform fracture, scattered crystalline points.
146b	ditto	ditto	—	2 241 000	1450	3360	53	24		0.00	0.020	Very fibrous, fine grey fracture, rough outside, but not cracked. Trace of arsenic.
B.—RAILS (Round Test Pieces).												
136a	Bolckow and Vaughan, Middlesborough	Chair Rail	1850	2 104 000	1020	3570	14	—				Chiefly coarse crystals, glittering two fibrous places. Rail had worn well for 25 years.
136b	ditto	ditto	1850	2 092 000	1030	3700	6	5.8				Fracture as above, one large fibrous place and crack near it. Wear as above.
45a	Royal Hungarian Iron Works.	Rail	1867	2 177 000	930	3210	9	—		0.005		Fracture as above, with a few fibrous spots.
45b	ditto	ditto	1867	2 076 000	1040	2820	16	4.7		0.01	0.32	Fibrous, but broke dark and short; crystalline spot at edge, and larger burnt spot in interior.
162a	ditto	ditto	1859	—	—	3460	22	17.7				Fibrous, but dull, honeycombed and dirty outside, badly cracked.
162b	ditto	ditto	1859	—	—	3510	23	15.2				As last.
170a	ditto	ditto	1868	—	—	3880	42	21.4				Fine irregular fibre, clear and dark, with one crystalline spot.
170b	ditto	ditto	1868	—	—	3780	49	18.5				As last, with a few small crystalline spots.
117a	Diosgyor Iron Works	ditto	1870	2 193 000	1430	3670	22	—				Fibrous with irregular gaping cracks, one crystalline and one brassy spot.
117b	ditto	ditto	1870	2 205 000	1900	3660	30	18.0				Fibrous, clear and dark, irregular; tore irregularly, cracks outside lengthwise and crosswise.
160a	Southern Ry. of Austria, Graz	Rail, Type VII.	1876	2 154 000	1300	3910	9	—				Mainly crystalline, coarse in middle.
160b	ditto	ditto	1876	2 124 000	1270	3720	7	7.5		0.05	0.238	Crystalline, irregular, with small fibrous spots, row of cracks outside. Trace of arsenic.
126a	Huttenberg Iron Works	Rail Head	1867	2 279 000	1230	3620	45	—				Very fine fibre, dark grey and clear, irregular, honeycombed; slight crack outside.
126b	ditto	ditto	1867	2 269 000	1780	3660	36	14.6				Fine dark grey fibre, irregular; broke irregularly; one yellow spot, lengthwise cracks outside.
127a	Aberdare Iron Co., England.	ditto	1868	2 126 000	1390	4220	6	—				Coarse crystals, cracks outside.
127b	ditto	ditto	1868	2 035 000	1540	3930	11	4.6				Coarse crystals, with dark fibrous spot and gaping crack, cracks outside.
48a	Laurahutte	Rail	1877	2 202 000	1780	3820	36	—				Fine fibre, with some whitish and one crystalline spot; outside rough, and cracked lengthwise.

1	2	3	4	5	6	7	8	9	10	11	12	13
No. of Piece.	Makers.	Application.	Year made.	Modulus of Elasticity. Kg. per sq. mm.	Limit of Elasticity. Kg. per sq. cm.	Breaking strength Kg. per sq. cm.	Contraction of Area per cent.	Elongation in 25 cm. (10 in.) per cent.	Analysis. Carbon per cent.	Sulphur per cent.	Phosph- per cent.	Remarks.
48b	Laurahütte	Rail	1877	2 184 000	1620	3740	43	22.6				Fine fibre, mixed light and dark grey; some crystal outside; cracked near fracture.
13a	Maxhütte, Regensburg	ditto	1869	2 000 000	1030	3340	40		0.09	0.15		Fine fibre, glittering points. Wear of rail very satisfactory.
13b	ditto	ditto	1869	2 166 000	1130	3600	35	21.9				Fibrous, with crystalline spots; outside rough, but not cracked.
47a	Pielahütte	ditto	1877	2 216 000	1410	4240	10			0.005		Crystalline and fine grained fracture, with two fibrous places.
47b	ditto	ditto	1877	2 161 000	1530	4180	3	3.0				Partly fine grain, partly coarse crystals, finely divided.

C.—BAR IRON (Round Test Pieces, unless stated otherwise).

154a	Anina Iron and Steel Works	Rounds	--	2 335 000	1730	4020	51					Uniform fine fibre.
154b	ditto	ditto		2 156 000	1940	3870	46	22.8				Fine fibre, not distinct, partly honeycomb; outside cracks lengthwise near fracture.
155a	ditto	Flats, 78 by 15 mm.		2 155 000	1660	3650	28					Fine layers, dark and light grey mixed irregularly. Flat test piece.
155b	ditto	ditto		2 149 000	1190	3660	38	27.7				Fine Fibre. Flat test piece.
17a	Dietrich & Co., Niederbronn	Squares, for Smiths	1875	2 043 000	1390	3730	53		0.12	0.005		Fine fibre, dark and light grey mixed irregularly.
17b	ditto	ditto	1875	2 210 000	1940	3720	39	26.0		0.00	0.106	Fibrous, dark and light irregularly, somewhat cracked; outside ditto. Trace of arsenic.
70a	Falkenroth, Kocher & Co., Haspe	Rounds, for Loco. Bolts	1877	2 210 000	1140	3360	31					Fine fibre, in layers, dark and light grey, small crystalline spots.
70b	ditto	ditto	1877	2 203 000	1970	3470	31	19.4				Fine fibre, with a broad dull crystalline band; cracks outside, chiefly lengthwise.
51a	Falva-Hütte, Upper Silesia	Smiths' Iron	1877	2 156 000	began at 500	3990	16			0.005		Coarse crystal, especially in broad band through middle. Good iron.
51b	ditto	ditto	1877	2 078 000	1000	3600	22	18.8				Main part crystalline, rest fibrous; outside badly cracked. Square test piece.
54	ditto	Smiths' Flats 57 by 10 mm.	1876	2 002 000	1250	3250	17	3.8				Fine layers, dark. Flat test piece.
44a	Ritter von Fridau, Leoben	Rounds	—	2 203 000	1130	2980	31			0.02		Fine fibre, in dark and light layers with whitish streaks through middle, and glittering spots; much honeycomb.
44b	ditto	ditto	—	2 160 000	1350	3570	33	21.1				Fine grain, some honeycomb; dull crystalline streaks; cracks outside.
40a	Funke & Elbers	Draw-bars	1876	2 198 500	2190	3980	45			0.03	0.221	Fine fibre, light and dark grey, irregular; glittering points. Some arsenic.
40b	ditto	ditto	1876	2 161 000	2000	3990	40	25.0				Fine fibre, light and dark grey, irregular; with dull crystalline patch, somewhat cracked.
43a	ditto	Flats, 20 mm.	1876	2 011 000	1370	4120	23					Flat test piece. Fine fibre, very irregular, with gaping cracks between layers. Works very well.
43b	ditto	ditto	1876	1 974 000	1170	3660	47	27.7				Flat test piece. Clear fine fibre, in layers; many streaky spots outside.
79	S. B. Goldschmitt, Mainz	Flats, 50 by 20 mm.	1876	2 265 000	1570	3890	30					Flat test piece. Fine fibre, somewhat short and flattened out.

(*To be continued.*)

NEW COMPRESSED AIR LOCOMOTIVE ON THE ELEVATED RAILWAY, NEW YORK.

A TRIAL was made on the Second Avenue elevated railroad, of a new air locomotive, with entire satisfaction to the Pneumatic Tramway Engine Company, who own the machine. In this locomotive, air at a high tension is stored in tanks and distributed to the motive cylinders through a reducing valve and then through hot water, according to an old and well-known plan, for the purpose of heating it, to counteract the refrigerating effect of the expansion of the air, and also to provide moisture as a lubricant for the pistons.

This locomotive was built by the Baldwin Locomotive Works, of Philadelphia, and is the invention of Mr. Robert Hardie, of Edinburgh, Scotland. It is on the same principle and an improvement on a street motor that was tested and reported on by General Haupt, whose report was published in the *Scientific American* supplement of June 28th, 1879. The obvious advantages of a noiseless exhaust, and the absence of fire, with its disagreeable odours, dust, and smoke in a street motor, are claimed for this locomotive, and so far as the experiments are concerned which have taken place in the last few days on the Second Avenue elevated road, the claim is well established.

The locomotive consists of four steel cylindrical air tanks of very perfect construction, having dished heads and triple riveted spiral seams in lieu of the usual longitudinal form, and double riveted circumferential seams, all of which are made tight by means of Connery's caulking, and tested at a pressure of 850 pounds to the square inch. These tanks, having an aggregate capacity of 460 cubic feet, are supplemented by two smaller distributing tanks, a small steam generator, and a pair of motive cylinders, similar to steam engine cylinders, 12½ by 18 inches, with Stephenson link reversing gear and adjustable cut-off on the back of the slide, connected in the usual manner to four coupled 42-inch driving wheels. The cab is located at the forward or cylinder end of the machine. The method of hanging by means of equalizing levers between the drivers and an improved two-wheeled swinging center bearing pony truck, effects the distribution of 80 per centum of the weight upon the drivers, and practically carries upon the three points of the frame, thereby avoiding undue strains and securing steady motion over the inequalities of the track. The initial air pressure is 600 pounds to the square inch at starting, but is distributed to the motive cylinders through the distributing tanks, reducing valves, and steam boiler, at a uniform working pressure, about the same as that of ordinary locomotives. A small fire is kept burning in the furnace of the steam generator, which is a small, upright, tubular boiler. For the purpose of obtaining a high grade of expansion and a noiseless exhaust, the cut-off is arranged on the back of the slide, as above stated, which is instantly adjustable to any desired grade by means of an ingenious hand device within the cab.

A new and peculiar feature of this engine is the use of the main cylinders for working the vacuum brakes, which is done by simply putting the reversing lever in mid-gear, when the main cylinders become vacuum pumps, thereby greatly simplifying the handling of the train.

On the 26th of October we had the pleasure of a ride on this admirable engine, and we testify to the perfect manner in which it fulfils its mission as a noiseless, odourless, smokeless, and perfectly controllable motor. It will cover the full length of Second Avenue, from 127th Street to the Battery, with four loaded cars, at a higher rate of speed than the schedule calls for, with a single charge of air, and then the recharging is done in as short a time as is needed to change horses on a surface road.

The engine is now in charge of John A. Wallace, one of the "L" road engineers, who is more than pleased with it, and especially is he delighted with the absence of anxiety about boiler water, which is the steam locomotive driver's bugbear.—*Scientific American.*

THE EXPLOSION OF A LOCOMOTIVE ON THE NORTH-EASTERN RAILWAY.—The coronor's jury which sat at South Stockton to inquire into the deaths of three of the victims of the locomotive boiler explosion near the Erimus Iron-works, has come to the conclusion, "that the explosion was caused by defective screw stays above the fire-door, allowing the fire-box front plate to bulge, and ultimately rupture, when the fire-box top was crushed down by the pressure upon it." The jury were further of opinion that "a number of vertical stays connecting the crown of the fire-box to the top of the outer casing were totally insufficient to take the stress coming upon them," and they think that "additional stays of a more efficient character should have been adopted."

NOTES.

Fires at Railway Stations.—The destruction of the Hammersmith railway station by fire will probably direct attention to the large proportion of wood used in the construction of some of our metropolitan railway stations, and also to the necessity for increased precautions. We are informed that the United Asbestos Company have introduced a paint which renders materials covered with it practically fireproof.

Australian Trans-Continental Railway.—We learn by the last advices from Queensland that General Fielding and the other members of the exploring party which had surveyed the country between the above colony and the Gulf of Carpentaria in connection with the proposed trans-continental railway are now at Brisbane. A special session of the Queensland Legislature is about to meet for the purpose of discussing the details of the projected railway.

Locomotive and Dynamic Engine Building.—It is not unreasonable to expect that some part of the large order for railway engines which has been sent over from America will find its way to Leeds, and the expectation is so confidently entertained that room is being made for the acquisition. Tramway locomotives are certain to become one of the largest special branches of our local iron industry. Kitson & Co. have such engines on lines all over the country, and have completed the stock which the Leeds Tramway Company will require when suitable rails have been laid on that system. Another Leeds firm of mechanical engineers is achieving remarkable success in this line. Manning, Wardle & Co., Boyne Engine Works, have received orders to make four more engines for the North Staffordshire Tramway Company. The interruption which occurred at J. Fowler & Co.'s, by the fire a month since, to the making of dynamo-electric machinery will be obviated in a few days, so extraordinary has been the expedition with which the work of restoration has been pushed forward.—*Ironmonger.*

Accidents on Indian State Railways.—The railways in India, Guaranteed and State, show a decrease in the number of accidents to trains, rolling-stock, permanent-way, &c., during the second quarter of the present year, as compared with the figures of the corresponding period of the previous one. The Rajpootana State Railway is the only one that shows an excess, there having been 47 more accidents this year than in 1880, during the same quarter. These accidents (832 in number) resulted in the death of 4 passengers against 6, and injury to 13 against the same number of the previous year. Seven passengers were killed and 39 injured from causes other than accidents to trains; while 51 railway servants were killed and 97 injured during the performance of their duty with the transit of passengers, but from causes other than train accidents. The total number of persons killed and injured during the second quarter of 1881, from causes connected with the working of trains, was 109 and 183, respectively, against 80 and 164 of the same period of last year. It is very noticeable that while Guarranteed Railways recorded only 12 accidents from the failure of machinery, springs &c., of engines, State railways numbered 55.

It is reported at Baku, says the *Indian Railway Service Gazette*, that the military Trans-Caspian railway is about to be purchased by a firm well known in the region of the Caucasus, which is already at the head of numerous industrial and commercial enterprises in that province. The line is completely finished for a distance of 217 versts up to its terminus, Kizil-Arvat, and trains have been running on it for some weeks. It will not be extended further, but it is in contemplation to establish a tramway as far as Bami, so there will be only 180 versts of road left in order to reach Askhabad. This road is passable for vehicles and is divided into four stages, to each of which there is a fortified station-house, where the horses necessary for the service of the Government are kept.

Street Lighting.—Six lamps have recently been fixed on each side of a section of Holborn with Siemens' patent burners, and at the "rest" opposite Gray's Inn Road, a massive lamp-post surmounted with a 44-inch octagonal lantern, fitted with a large burner of the same patent, giving a light of 280-candle power at a consumption of 55 cubic feet per hour, has also been placed. The effect is very brilliant and the light powerful. As this section will be in close juxtaposition to the electric light an opportunity of contrasting the two methods of lighting will be afforded. The lamps were fitted up by Moxon D. Hulett & Co.

CORRESPONDENCE.

CANONBURY DISASTER.

To the Editor of "THE RAILWAY ENGINEER."

SIR,—On reading the report of Colonel Yolland to the Board of Trade on the Canonbury accident, he states that the collisions were the direct result of the unauthorised mode of working the four passenger trains introduced by signalman "Hovey," and that "this man made a great mistake."

Now, in a perfect absolute block system it ought to be quite out of the power for a signalman to lower his signal a second time until he has been released by the man in advance. Hovey appears to have worked the permissive block, but if the evidence of the drivers, firemen, and guards is to be believed, he must have done this by means of his signals or semaphores, whereas, if a system like that on the Metropolitan District Railway had been in use, this would have been impossible.

The Colonel states "that he has received various suggestions, that had the electrical and out-door signals been interlocked with each other, and that it should not have been possible for the up-starting signal worked from No. 1 Great Northern Box to have been taken off without the consent of the signalman in the Canonbury Junction Signal Box by one of the various systems now in use, collisions could not have happened," and he further says, "But that is not so," for, he continues, "wherever the permissive block system is introduced, trains are frequently signalled forward by hand signals while the home signals stand at danger."

It is a well understood rule amongst drivers when they receive a hand signal, they proceed with the utmost caution; such being the case Colonel Yolland, who is entitled to be heard with the greatest respect, will pardon us in saying that had such a system as he refers to, and is now working on the London, Chatham, and Dover Railway, been in use, the collisions under consideration could not have taken place, because where three men are mechanically locked together, no matter what distance they are apart—and it is out of one signalman's power to unlock the levers of the man in the rear more than once until the advancing train has arrived at his own box, and he, by permission of the signalman ahead has passed the train into the section in advance—he cannot allow the man in the rear to let another train come on. It will be seen at once that it is impossible for three trains, much less four, to be in one section at the same time.

Let us now examine the Colonel's report and see if a proper combined lock and block system had been in use, what would have been the result? The starting signal at Finsbury No. 4 Box would have been locked by No. 1 Great Northern Box, and the home signal at No. 1 Box would also have been interlocked with the starting signal, so that the home could not, after having been once lowered, be used again until No. 1 Great Northern—*i.e.*, Hovey's Box, had lowered his starting signal, which would be locked by Canonbury Junction. The same form would be gone through with the Junction Box and that at the west-end of Canonbury Station.

Now, on the 10th of December last a train was sent forward to Canonbury Station from Canonbury Junction about 8.45 a.m., and some time after, at 8.54, the man at the Junction gets "line blocked" from Canonbury. With the system to which we have alluded, the act of the man at Canonbury Junction passing the train towards the station would have immediately and mechanically caused the instruments to show "line blocked." He would not have waited nine minutes for it. And, again, as soon as he had put his levers to danger they would have been automatically locked, and Canonbury Station could not have unlocked them again until he had got rid of the 8.45 train.

To quote Colonel Yolland's report again, he says, "at 8.55 according to the register book in Great Northern Signal Box No. 1, and also according to the Signalman Hovey's statement, he sent the 'be ready signal' for an up passenger train on from No. 1 Box to Canonbury Junction by giving the beat on the telegraph instrument which was acknowledged by Hill by the beat from Canonbury Junction, but the needle or indicator on the instrument was not moved by Signalman Hill in the Canonbury Junction Box." Now, if the above-mentioned system had been in use, the words "line blocked" would have appeared in Signalman Hovey's Box by the act of his lowering his starting signal for the 8.45 train, and he having once unlocked the starting signal at Finsbury Park for the 8.54 train, lowered his home and brought the train up to his starter, he could not by any means have lowered it until released by Canonbury Junction, nor could he have again unlocked the starting signal at Finsbury Park until his own starter was lowered for the 8.54 train, and the lever put back to danger, as until this was done the block instrument in the direction of Finsbury Park would not have acted.

Again, if the system referred to had been in use, the signalman at Finsbury Park must also have flagged the last three trains as well as Hovey, as the stop signal or starting at Canonbury Junction would have been locked by Canonbury West, the starting signal at No. 1 Box by Canonbury Junction, the home signal at No. 1 Box locked at danger until the starter was used and put back to

danger, and the starter at Finsbury Park would have been locked by Hovey in No. 1 Box, and it was mechanically out of his power to have unlocked it a second time until his own starter was lowered and put back to danger.

So, we still think that the improvements and appliances of modern times would have prevented the Canonbury disaster, and although it be perfectly correct to state that no system of signalling can prevent men waving trains past signals at danger, nor drivers themselves running against signals, where a system is introduced that leads to a combination of stupidity on the part of three or more signalmen, one after the other contravening orders. In justice to the signalmen and to the drivers we do say that we never heard of such a case, and it would be a sorry and a sad confession for railway engineers, electricians, and mechanicians if it were to be proved that accidents on railways were not, as we have endeavoured to prove in this case, preventable.

I am, Sir, Your obedient servant,

SIGNAL ENGINEER.

OFFICIAL REPORTS ON RECENT ACCIDENTS.

LANCASHIRE & YORKSHIRE RAILWAY.—BLACKBURN COLLISION.

MINUTE OF THE BOARD OF TRADE.

At the Council Chamber, Whitehall, The Eleventh day of January, 1882.

Present: The Right Honourable JOSEPH CHAMBERLAIN, M.P.

The Board of Trade have carefully considered Colonel Yolland's report upon the circumstances which attended the collision on the 8th August last, between two express passenger trains, at the Blackburn station of the Lancashire and Yorkshire Railway.

From that report it would appear that Colonel Yolland is of opinion that the accident arose from two causes,—(1), the imperfect working of the Blackburn station on the permissive block system; (2), the failure of the automatic brake.

Colonel Yolland is of opinion that, although the permissive block system may, under stringent and proper regulations, be worked with comparative safety, yet that it is a system which, if not strictly worked, is likely to lead to collisions, as it appears to have done in this case, and that the collision in question would in all probability not have occurred had the absolute block system been in use.

Colonel Yolland also concludes, from the evidence taken at the inquiry and from the experiments subsequently made, that some of the mechanism of the brake with which the train was fitted had become out of order, and that the brake consequently failed to act properly when required to prevent a collision, which was primarily caused by a failure of the permissive block system. This conclusion is not founded on such direct and positive evidence as to place it beyond doubt, but on inferences drawn from a variety of circumstances. On the other hand, there is evidence that the brake was in order, and had acted properly on this journey, at the preceding stations at which the train had stopped.

The attention of the Company should be called to the danger attending the working of the permissive block system; in doing this, credit must be given to the Lancashire and Yorkshire Railway Company for having adopted the absolute block system upon most sections of their railway.

With regard to the alleged failure of the brake, the Company's attention must also be directed to the suggestions which Colonel Yolland has made respecting the imperfections of the brake and the remedies which, in his opinion, would remove present causes of failure. But it must be remembered that all mechanical contrivances are at times liable to get out of order and continuous brakes are no exceptions to this rule, particularly as they have to be fitted to trains composed of large numbers of carriages, often requiring to be interchanged on a journey, thus involving repeated coupling and uncoupling of the carriages, and the repeated connection and disconnection of the brakes. The Company's attention ought, therefore, to be directed to the necessity of giving most careful instructions and warning to those who are entrusted with duties, upon the proper performance of which the due operation of the brakes necessarily depend.

Finally, the Board of Trade, as at present advised, after careful consideration of Colonel Yolland's report, and after a reconsideration of the conditions which they have repeatedly laid down as being desirable in all continuous brakes, after consultation with their inspecting officers, and after consideration of the experience gained during the last few years, have come to the conclusion that while it is essential that the defects in the automatic brake to which Colonel Yolland alludes should be provided against, and every precaution taken to ensure the brake acting only when required, yet there is no reason to withdraw the opinions they have previously expressed as to the conditions which should be observed in providing brake power for passenger trains.

J. CHAMBERLAIN.

Colonel Yolland has reported the result of his inquiry into the circumstances which attended the terrible collision that occurred in the afternoon f the 8th of August last between two express passenger trains at the Blackburn station of the Lancashire and Yorkshire Railway. An express passenger train from Liverpool to Todmorden was standing at the platform of the Blackburn station when it was run into by an express passenger train from Manchester to Hellifield on the Midland Railway, travelling at a speed variously estimated at from 15 to 30 miles an hour. 1. From the statements it appears that the 2.10 p.m. Liverpool express passenger train to Todmorden reached Blackburn at 3.9 p.m., three minutes late, and the engine stopped just clear of the roof over the station at the north-east end of the platform. The saloon carriage next the tender was at once uncoupled from the vehicle behind it, and the engine drew it ahead, and placed it in No. 1 siding. The engine then returned to the train and was coupled on to it in readiness to start. In the meantime, another engine had passed from the cross-over road between the up and down main lines, to the rear of the Midland bogie carriage, placed at the tail of the Liverpool express train, from which it had been uncoupled, and this carriage was hooked on to this engine in readiness to be pushed on ahead as soon as the Liverpool train had left the station; but this did not happen until after the collision had taken place. The 2.25 p.m. Manchester express train to Hellifield is stated to have left Manchester at its appointed time; it is due at Blackburn at 3.14 p.m., and arrived there and the collision occurred a 3.15 or 3.16 p.m. It was thus allowed 49 minutes for the journey of 24½ miles, with two actual stoppages, and a reduction of speed at each end of the Sough tunnel. This train consisted of an 8-wheeled tank engine and seven vehicles including a brake-van, which was the third vehicle from the engine. It was fitted throughout with the Westinghouse automatic air pressure brake, with brake-blocks on the leading and driving wheels of the engine, and on all the wheels of the vehicles in the train with the exception of the centre wheels of four of the vehicles which were 6-wheeled coaches. In addition to the Westinghouse brake there was a hand-brake on the engine which applied to the driving wheels only, and another in the 4-wheeled van, which could be put on by the guard riding in that van. The arrangements connected with the Westinghouse automatic air pressure brake, permitted it to be put on by the engine-driver on the engine, or by the guard in the van, as already stated. This train is appointed to stop at Bolton, Over Darwen, and Blackburn stations, and it is said to have been brought to a stand at Bolton and Over Darwen stations by the use, by the engine driver of the Westinghouse brake, and by the fireman using the hand brake on the engine, and the speed was also reduced by similar means in order to pick up and drop off a single line conductor at Sough tunnel, which is under repair, before reaching Over Darwen. The driver Stansfield states that he noticed the air pressure in the gauge glass on the engine for the Westinghouse brake as having stood a little over 80 lbs., and he noticed it last before coming off the branch. He says he tried to apply the automatic brake just after passing over the Bolton junction, having previously applied the hand-brake on the engine on approaching that junction, but found that the moving of the brake lever up to the stop (called in his statement the little lever) did not cause the automatic brakes to take effect; he thinks it was the application of the hand brake on the engine which reduced the speed from 40 to 25 or 30 miles an hour, and he thinks he moved the little lever when he was running at 25 or 30 miles an hour; that the speed was not reduced very much when they passed the Old junction, and after passing the Old junction he reversed his engine and gave her steam, but he does not think he had finished the reversal of the engine when he passed the West Cabin, and he whistled for the guard's brake after he had given the engine steam, after reversing it, when he perceived that the brake was not acting, and that there was a train in the station, which he noticed after passing the Old junction. This man's evidence is confirmed by that of the firemen, who was very seriously hurt, and by that of the guard of the train whose evidence I took while he was lying ill in bed. The guard, James Wade, estimated the speed on the branch to be about 45 miles an hour, and "on passing the Old junction," he says, "the speed had been reduced to about 35 miles an hour;" he had not heard any whistle from the engine up to that time; he concluded that the diminution of speed was caused by the driver attempting to pull up. And he further says that the application of the Westinghouse brake usually distinctly tells a guard that it has been applied. There had not been any such intimation conveyed to his mind that the Westinghouse brake had been applied. That he was certain that such diminution of speed must have been caused by the application of some brake, and he thinks that the application of a hand-brake on the engine would have done it. The guard heard a couple of sharp whistles, but could not say whether they were whistles from their engine or from an engine which was standing in a siding on the opposite side; that his van had by that time just passed the West Cabin, and they were then running 30 miles an hour. He thought the Westinghouse brake had not been applied up to the time when he heard the two whistles, and he was not sensible that the Westinghouse brake had been applied after hearing the two whistles, and he had not applied his own hand-brake up to that time; that they had reached the platform when he heard the two whistles; that there was no sensible diminution of the speed after passing the West Cabin that he could observe; that he opened the valve of the Westinghouse brake in the van after they had passed the West Cabin and did not hear any rush of air, and after opening the valve of the Westinghouse brake, he put on his hand-brake, and had got it on just before the collision took place; that he knew that steam was given to the engine when entering the station, and he could feel the

reversal of the engine in the van, and he did hear the slipping of the wheels; he thought they were going about 20 miles an hour when they struck the other engine. The fact of the reversal of the engine and the application of the steam the reverse way and the whistles for the brakes, is, I think, distinctly proved by other testimony, and cannot, I imagine, well be doubted. It must, however, be recollected that this was the first occasion on which driver Stansfield had driven the Manchester express train to Blackburn, and he had only driven trains fitted with the Westinghouse automatic air pressure brake on seven previous occasions, and then he had an experienced fireman with him. 2. I was unable to obtain any precise information of the actual condition of the Manchester express train, immediately after the collision occurred. I could not learn what brake-locks were on the wheels of the engine, or of any of the wheels of the carriages or van in the train, neither could I ascertain what was the position of the brake valve lever on the engine to show whether the driver had correctly stated that he had moved it up to the "stop," so as to put the Westinghouse brakes full on, and had so left it, when he jumped off the engine, immediately before the collision took place. Neither would the fact of the brake valve lever having been moved up to the "stop," prove that the brakes actually acted; but it would have shown that the driver did what he could to cause them to act. The hose connection between the engine and the Lancashire and Yorkshire composite carriage No 240, next to it, was found properly coupled up, but the hose pipe between this carriage and the North British composite No. 240, behind it, was fractured, and that fracture should have sufficed to have put the brakes on even after the collision had taken place, if the main brake pipe along the carriages had been charged with air, supposing that the engine driver's statement that he had tried in vain to put them on were correct, corroborated as that statement is to a certain extent by that of the guard, "that he had also endeavoured to apply the Westinghouse brake from the van." Again, the four carriages behind the guard's van which were not damaged, were moved some time after the collision had happened, and when they were moved it appears certain that there were no brake-blocks on the wheels of those four carriages, or the engine which was brought from the shops with the brake-down van could not have moved them. The precise time when they were moved is somewhat doubtful. Signalman Thompson (at the West Cabin) says "the brake-down van arrived at 3.27. I have no record when the brake-down van again passed my box." It was the engine belonging to this train which moved the four carriages. The station master Howard says, "After I had made the necessary arrangements for attending to the killed and injured, and it would probably be within a quarter of an hour, I went along the Manchester express train, and there was a light engine on the same line of rails, behind the Manchester express, and that engine was made use of for drawing the four carriages back. The brake-blocks on these carriages were all off, and not in contact with the wheels." The locomotive foreman, Grafton, says it was "done at 3.35 p.m." (which would be 19 or 20 minutes after the collision had taken place), while the carriage-inspector, Jones, says "it might be a quarter of an hour before the carriages were hauled away." An engine driver, Archer, heard of the collision in the town at 3.30, and "went directly to the station, and got there at 3.45 p.m." At that time four coaches at the rear of the Manchester train had been removed. 3. Several representatives of the Westinghouse Brake Company were present at my inquiry, and every facility was throughout given to them in reference to the putting of any questions they wished the persons under examination to answer. I had also received from the Westinghouse Brake Company printed copies of their last published work on the subject of their brake; I visited their workshops at Canal-road, King's-cross, and received full explanations from Mr. Simonds as to the working of the brake, and I was furnished with copies of statements taken down from persons who were travelling in the Manchester express at the time of the accident, and was told that they intended to call these persons at the inquiry before the coroner. I informed the representatives of the Company, more than once, that I was quite prepared to hear what any witnesses they might desire to call could state, as to any facts bearing upon the case, or to receive any statement which they might think proper to make, after hearing all the evidence, and noting all the experiments which were made, and I informed Mr. Westinghouse that I would delay making my report for ten days, as he was obliged suddenly to go on the Continent before my inquiry had finished. Ultimately I was told, that they would call the persons they desired to examine at the inquiry before the coroner; and they only called one of their inspectors before me, to explain some conversation which had passed between him and the driver, Stansfield, of the Manchester express, which the latter had interpreted as a suggestion that he should go to America, and avoid the attendance at the coroner's inquest. (4.) As the result of their attendance, the questions which they put to the witnesses and the information they have sent me, I inferred that they doubted altogether the accuracy of the statements made by the Company's servants in charge of the train, as to any failure of the Westinghouse brake to act throughout the entire length of the Manchester express train having taken place; and in consequence of what passed on the first day, I requested the officers of the Lancashire and Yorkshire Railway Company to be good enough to provide a train similarly made up in all respects to the Manchester express (which, however, had no weight added for passengers), that certain experiments might be made in running down the incline from Over Darwen to Blackburn station. The total weight of the train so made up was 123 tons $3\frac{3}{4}$ cwts.; the engine weighed 49 tons $\frac{3}{4}$ cwts., and there were brakes on the leading and driving wheels of the engine, with a weight on them of 28 tons

18¼ cwts., while the hand-brake on the engine applied only to the driving wheels having a weight of 15 tons 2½ cwts. on them. The weight on the wheels of the vehicles in the train amounted to 74 tons 3 cwts., and brakes were fitted to the wheels of the vehicles having a total weight of about 50 tons 13½ cwts. on them. The first experiment that was tried was a failure, as the driver Stansfield was told to run the train at the same speed and under the same circumstances as to shutting off steam and applying the brakes, as on the day of accident, and he misunderstood the order. The next experiment was properly carried out, the steam was shut off, and the automatic brakes were applied at the Bolton juction. The train was running as near as possible at the rate of 50 miles an hour, and it was stopped in a distance of 240 yards, between the Bolton junction and Old junction signal-boxes, or 115 yards short of the Old junction signal-box, and 413 yards short of the spot where the collision had taken place. This experiment shows what the brakes would have accomplished if they had been effective throughout the whole length of the train, and had been properly applied. It had further been stated on the first day by a representative of the Westinghouse Brake Company, that if the hand-brake on the engine had been applied as stated at the Bolton junction, on a similar train travelling at 40 miles an hour it would have been stopped at the spot where the collision occured. It was useless to argue such a question, and I therefore requested the officers of the railway company to run two more experiments down the incline from Over Darwen to Blackburn, while I went on to attend at the Coroner's inquest. These were superintended by the assistant locomotive superintendent, Mr. Evans, and the hand-brake on the engine only was applied to stop the train in the first experiment. Mr. Evans estimated the speed at 40 miles an hour, but it was timed by Mr. Gutch, one of the representatives of the Westinghouse Brake Company, and he found it to be not far from 50 miles an hour. The train took rather more than 1,250 yards to pull up in, instead of the 671 yards between the Bolton junction and the spot where the collision took place. The other experiment was run immediately afterwards, where the hand-brake on the engine was applied, and the engine was reversed and steam applied at the spot pointed out by the driver, Stansfield, and the speed was stated by Mr. Gutch to be 50 miles an hour. In this instance the train ran right through the station into the tunnel beyond it, and had to be stopped by the Westinghouse brake, considerably exceeding the distance run in the previous experiment. The damaged train (Manchester express) was put together, and steam was got up on the engine, and when the proper pressure had been obtained in the brake pipe, the brake was applied. I was informed by Mr. Simonds, another representative of the Westinghouse Brake Company, that there was a leak from the brake-cylinder under one of the carriages, which he supposed was the result of the collision, but another representative (Mr. Gutch) informed me afterwards that one of the cocks was open under that carriage, and that allowed the air to escape. I do not know which was correct. The brakes were kept on, and did not leak off for upwards of a quarter of an hour, and the engine could not move the train while this was the case. Portions of the machinery connected with the brakes of the damaged Manchester express were examined at the resumed inquiry in September. Some of the triple valves were rather dirty, others were clean, but the triple valve on each vehicle would only effect the brake on that vehicle, and would not account for the stated failure throughout the vehicles of the train. The officers of the Railway Company were of opinion that the hose pipe had become disconnected from some cause or other, between the first and second vehicles, but I was not furnished with any evidence to prove that it was found so disconnected, immediately after the collision had taken place. Hence, at the resumed inquiry, it was deemed desirable to make another experiment between Over Darwen and Blackburn with the same train at the same speed, which I am satisfied would be about the speed which the Manchester express train would probably have attained in running down the incline on the day of the collision after shutting off the steam at the spot pointed out by the engine-driver; and in this experiment the Westinghouse brakes were applied only to the wheels of the engine and the vehicle next to it, and the train stopped about 10 yards short of the spot where the collision had occurred, thus going far to disprove the supposition that the disconnection in the hose pipe had taken place between the first and second vehicles from the engine. Another, and last, experiment was tried, at my request, when the Westinghouse brake, on the engine wheels only was applied at the Bolton junction, while the train was running at the same speed, and it was stopped about 200 yards beyond the place where the collision had occurred, and where it must, as on the day of the accident, have been running at high speed when passing the centre of the station, supporting an assumption that the Westinghouse brakes were only effectively employed on the wheels of the engine when the collision took place. It should, however, be noted that on this day the rails were dry and favourable for stopping, while on the 8th August they are said to have been very greasy and unfavourable for stopping. 5. Thus the actual position of this case, as presented to me by the evidence of the Company's servants in charge of the Manchester express train is, that the pressure in the main brake pipe on the engine stood at 80 lbs. in the gauge glass immediately before the engine-driver endeavoured to apply the automatic brakes, in addition to the hand-brake on the engine, at the Bolton junction, 671 yards from the centre of the station, but on finding that the brakes did not act on passing the Old Junction 316 yards from the same spot, the driver reversed his engine and applied the steam the reverse way, and then whistled for the guard's brake on passing the West Cabin, 172 yards from where the Liverpool train was run into. The most convincing proof which was afforded me that the driver Stansfield's state-

ment is to be relied on is to be found in the fact that he certainly did reverse his engine and apply the steam the reverse way, after passing the Old Junction, 316 yards from the spot where the collision occurred, whereas if the Westinghouse brakes had been in an effective state throughout the whole length of the train at that spot, even if they had not been previously attempted to be put on, there was still ample distance for the train to have been pulled up short of the shunting engine at the tail of the Liverpool train. The reversal of the engine was the last thing an engine-driver could do under such circumstances. 6. There is no way of accounting for the non-action of the automatic brakes on this occasion that I am aware of, except on the supposition that the hose pipes had not remained coupled together, or that a valve somewhere in the main brake pipe had closed and prevented the free passage of air; because the driver distinctly stated that the brakes had previously acted properly at Bolton, Sough tunnel and Over Darwen. Mr. Wright, the Company's Locomotive Superintendent, however, informed me that there had been a case at Stanningley on the 20th April last, when a passenger train had overrun the station platform 200 yards. This case is mentioned in the printed returns of the failures of the continuous brakes during the half-year ending on the 30th June last, forwarded by the railway companies to the Board of Trade, and printed and published; but the return sent to the Board of Trade does not correspond with Mr. Wright's report to the railway company, as it did not mention the train having overrun the platform 200 yards. I saw the original report, and the following is a copy of it :—

" Description of Brake. Date of Failure.
" Westinghouse.
" Engine No. 392 with 4.45 p.m. passenger train Manchester to Leeds ran past Stanningley station 200 yards in consequence of the air pipe between engine and train becoming uncoupled, causing a delay of 14 minutes. This was caused by the screw on the air pipe having got twisted by the lock nut slacking back, thus allowing the couplings to become disengaged."

This case has been further looked into since I was in Manchester. Another case was referred to in the evidence brought before me of the hose coupling having become uncoupled on the 29th August at Leeds station on the 9.0 a.m train from Leeds to Lowmoor. I was also shown experimentally in the company's workshops at Newtonheath, how easy it was for the hose-pipe to be wrongly coupled up, and then to be become disconnected, and when this disconnection takes place there is nothing to indicate to the driver of a train, fitted with the Westinghouse automatic air pressure brake, that, instead of having the power to apply the brakes on the wheels of the whole of the carriages in order to arrest the progress of his train, he may possibly have the brakes on the engine alone to depend on. I had also heard of a somewhat similar case to that at Stanningley as having happened on the London, Chatham, and Dover Railway, when the Dover boat express train had run through the Dover Station, a train and a half's length, on the 1st January last, when the engine was in the hands of an experienced driver, and I wrote to the Company's Locomotive Superintendent (Mr. Kirtley) and found that it was the case. In these cases, at Stanningley and at Dover, if there had been trains standing in the stations at the time when these overrunnings occurred there would probably have been serious collisions. I then turned to the printed returns (in pursuance of the Railway Returns (Continuous Brakes Act, 1878), by the railway companies of the United Kingdom for the half years of 1879, 1880, and to the 30th June, 1881 as reported by the various railway companies, some of which have adopted the Westinghouse automatic brake, and some have not. The railway companies are required to furnish particulars of the failures of the brakes under the three following heads :—1. Failure, or partial, to act, when required in case of an accident to a train, or a collision between trains being imminent. 2. Failure, or partial failure, to act under ordinary circumstances to stop a train when required. 3. Delay in the working of trains in consequence of defects or improper action of the brakes, distinguishing whether they arose from neglect or inexperience of servants or failure of machinery or material. I found that there were few cases of failure reported under head No. 1. Many under No. 2, which would embrace cases of running through stations from the failure of the brakes to act when required, and of others where the trains were suddenly pulled up from no action on the part of the engine-driver, and a very large number indeed under the head No. 3. These failures present a strange contrast with the small number of failures reported by the Metropolitan District Railway Company, which only uses the Westinghouse air pressure, but not the Westinghouse automatic brake. Thus in those five half-yearly returns, during which the Company ran 2,148,316 miles, 13 failures in one half-year and one in another only are reported and stated to be due to the defective condition of the air-pump. I should, however, state that the over-running of platforms or through stations is not limited to trains fitted with the Westinghouse automatic brake, but is found to occur with other brakes. 7. The causes which led to this collision must be considered under two different heads when looking to the question of the safety of the public travelling on the Lancashire and Yorkshire Railway into Blackburn station in future. The first head embraces the question whether the passenger traffic can be safely conducted into the Blackburn station from Manchester, under the permissive block system, as worked on the day when the collision took place, when the home or stop-signals at Bolton junction, the Old junction, and the West Cabin were all off, while the distant-signals worked from the Old junction and the West Cabin, were both on at "danger," a green flag being shown, from the West Cabin to the Manchester express train, there being another train standing in the station at the time. I may remark that, according to the general practice of railways in the United Kingdom, the distant-signal, when exhibited at "danger," is regarded only

as a caution signal, requiring the engine-driver to be prepared to stop at the next home signal ahead if it is exhibited at "danger" against him, and the driver, on coming in sight of that next home signal and finding that it is "off" and not standing at "danger" against him, and that the distant-signal worked from the next signal-box ahead is likewise at "danger," will know that this last distant-signal is merely a caution signal, directing him to be prepared to stop at the next home-signal if it stands at "danger," but not otherwise, and thus he will continue to run ahead until he arrives at the usual place in the station for pulling up. There are, however, considerable differences of opinion among the signalmen employed at the Blackburn station, according to the evidence given before the coroner and at my inquiry, as to what the Company's rules and regulations, as quoted by me, actually requires them to do, but as interpreted by the signalman on duty in the West Cabin (Thompson), I am only surprised that many serious collisions have not previously taken place at Blackburn Station if the practice he adopted had been generally followed, as he told me that "I did what was right in lowering the home signal for the Manchester express to run past my box at 40 miles an hour, when a train (the Liverpool) was still standing at the platform;" and again, "I have never had any instructions, written or verbal, to keep my home signal at 'danger' when a train is standing in the station against an approaching train coming at a high rate of speed, until that train has either stopped or nearly come to a standstill." This man's box, the West Cabin, being only 172 yards from the spot in the centre of the station where the collision took place, the safety of any train coming from the south and of another standing in the station, almost entirely depends on what is done with the home signal when that other train is arriving. I do not consider that the Rule 153, and note to rule 163, are as clear and distinct as they should be for the proper guidance of the signalmen, and think the rules should be made more definite and positive. I do not say that traffic cannot be safely worked through a station on the permissive block system, and it certainly may be done under explicit rules and regulations, and implicit obedience to them, the discipline being rigidly maintained; but it would be far better to increase the accommodation at important exchange stations, like Blackburn, and avoid the use of the permissive system altogether where it is possible to do so. If, however, I am to believe the evidence of the engine-driver, fireman, and guard of the Manchester express train, the improper working of the home signals at the West Cabin and Old junction had nothing whatever to do with causing the collision to take place; but I think it is highly probable that if the home signals at the West Cabin, Old junction, and Bolton junction had all been exhibited at "danger," the engine-driver would have commenced to reduce his speed as he approached the Bolton junction, and not as he passed it, and the collision might have been altogether avoided, or, at all events, greatly mitigated in its results, notwithstanding the stated failure in the action of the brakes. 8. There is one consideration in connection with this collision to which I must call particular attention. Mr. Stanhope's letter of the 21st April, 1877, from the Board of Trade to the Chairman of the Railway Companies' Association, asking for information as to what was being done by the different railway companies respecting continuous brakes, has the following question: — "4 What are the results? *A.* As to efficiency in stopping trains, and especially whether the brakes can be applied instantaneously, and whether, in case of accident, they are self-acting?" No one can question, I imagine, the desirability of the continuous brakes being made, "in case of accident, self-acting," if that can be accomplished without introducing any other element of danger. The self-action can probably do no harm in such cases, and in some may do good, but it is quite a different thing when any of these continuous automatic brakes become self-acting when there is no accident, and suddenly arrest the progress of a train when it is not required by the driver to be stopped; or, on the other hand, refuse to go on and act, from any cause whatever, when the driver desires to pull up his train in order to stop at a "danger" signal, or at the proper spot at a station, or to avoid any obstruction whatever which he may suddenly come upon, such as cattle straying on the line. No great harm is done as far as the public safety is concerned, by the brakes suddenly going on without any action on the part of the engine-driver, where the traffic is strictly worked on the absolute block system, and two trains are not permitted to be on the same section of the line between two signal-boxes at the same time, beyond the delay thus occasioned, which however is frequently a great nusiance to the passengers; but the case is altogether different where failures take place in the working of the absolute block system, or where it is replaced by the permissive system, as through Blackburn station, and two trains are allowed by the system of working adopted or by mistake on the part of one of the signalmen to be on the same section at the same time, and collisions take place like that in the Bleamoor tunnel, on the Midland Railway, on the 19th August, 1880, when three passengers were injured, and that at Bow Road station, on the Stepney and Stratford branch of the Great Eastern Railway, on the 3rd ultimo, when 11 passengers are returned as having been injured, and the driver and fireman of an engine of the following train sustained fatal injuries, and died on the spot, from the action of the brakes suddenly stopping the leading train where no stoppage was required, and where the engine-driver did all in his power to avoid the stoppage. It is quite true that, if the signalmen concerned in both these cases had done their duty in correctly working the block system, the collisions would not have occurred; neither would they have happened had not the trains been unnecessarily stopped by the action of the brakes. I may remark that the absolute block system is now stated to have been adopted on 11,597 miles of railway up to the end

of the year 1880, and that 5,321 miles still remain on which the absolute block system has not been adopted; but the former figures probably include the lengths of a very large number of stations where the permissive block system, or what is sometimes called station-system working, is substituted for the absolute block, and it is there that future collisions may be expected to happen from similar causes. 9. The Westinghouse automatic air-pressure brake is a very clever, ingenious piece of mechanism, made up of a very great number of separate parts, to give it the automatic action; but, as is well known, the greater the number of parts in any piece of mechanism, the greater is the liability of failure, and I consider that the liability to apply itself when not required, and when there is no accident, and to fail to act or go on when absolutely required by an engine-driver, constitute two grave defects in its present construction. These defects are produced, 1st, by automatic action in the hose-pipe connections by which they frequently become uncoupled by a twisting of the pipe when air is admitted from the engine, when there is no accident of any kind, and no indication is conveyed to the engine-driver of the hose connection having become uncoupled; and as a result, the action of the brakes when applied by the driver is limited to the brake on the engine alone or to those on the engine and such other vehicles as remain connected by the hose pipes to the engine. 2nd. The automatic action, by which sometimes the brakes go on and suddenly pull up a train when they are not required by the engine-driver to go on, is probably caused by leakage from the pipes when there has been no accident, nor any separation of the train into two or more parts, which alone requires the proper automatic action of the brakes to be brought into play. Whether it is possible to get rid of these defects I offer no opinion. But I must point out that some alteration is certainly required in the hose connections to render it impossible for them to be wrongly coupled up, by nigh as well as by day, and thus avoid the frequent cases in which they subsequently become uncoupled; a plate should be fixed under the brake-valve lever, on the engine, to indicate the proper position of that lever when the brakes are required to be released, its proper position to keep the brake blocks off the wheels of the train while running, and its proper position for effecting an easy stop, or as rapid a one as is possible, in case of necessity; and provision should be made for a tell-tale on the engine to let the engine-driver know what is the pressure in the brake-pipe at the rear end of the train. Until these defects are got rid of I do not think the Westinghouse automatic air-pressure brake should be employed where the absolute block system of working is not rigidly upheld. 10. The automatic action of continuous brakes was apparently designed to avoid the cases of collision arising from a passenger train having suddenly separated into two parts unknown to the engine-driver, where the after part might in consequence come into collision with the front part on its slackening speed, or run back while ascending an incline and come into collision with a following train. But these two causes of producing collisions would be provided against if railway companies were compelled to comply with the law, and establish and maintain an efficient means of communication between their servants in charge of the trains and the public riding in the carriages, when the separation of the train into two parts would at once be made known to the engine-driver, and he would be enabled to avoid the front part of the train being run into, while as regards the running back down an incline of the separated after part of the train, this would be provided against by having sufficient brake power at the after part of the train, under the control of the guard, to prevent it from running back. 11. The Lancashire and Yorkshire Railway Company was one of the earliest among railway companies to supply a larger proportion of brake power to their passenger trains, by means of what are now called sectional continuous brakes, extending over a portion of the carriages in each train, and Fay's and Newall's brakes are well known and extensively used on many railways; and I have heard it stated among the officers of this company that their use has saved them from many a serious collision. But I understand that this railway company had fully determined to give the Westinghouse automatic air-pressure brake a fair trial on their line, and this is, I think, proved by their having had eleven engines and thirty-six carriages fitted with this apparatus; three tank engines having been thus fitted during the half-year ending 30th June last. I need scarcely add that I have received every assistance in carrying on this investigation from the Officers of the Lancashire and Yorkshire Railway Company.

Colonel Yolland has reported the result of his inquiry into the circumstances which attended the three collisions that occurred on the 10th December last, in the tunnel on the Canonbury branch of the Great Northern Railway Company which connects the Great Northern Railway at Finsbury Park with the North London Railway near Canonbury. From the statements it appears that an up North London passenger train from Finsbury Park on the day in question (10th December) was sent forward by the signalman from Canonbury junction to Canonbury station about 8.45 a.m., and some after that (at 8.54 a.m.) "line blocked" was received at Canonbury junction from Canonbury station. This "line blocked" was given from Canonbury station in consequence of a tube in an engine having burst at Dalston, and thus temporarily stopped the traffic. Again, at 8.54, according to the register book in the Great Northern signal-box No. 1, and also according to the signalman Hovey's statement, he sent the "be ready" signal for an up passenger train on from No. 1 box to Canonbury junction signal-box by giving one beat on the telegraphic instrument, and this was acknowledged by signalman Hill by one bell from Canonbury junction, but the needle or

indicator on the instrument was not moved by signalman Hill in the Canonbury junction signal-box to "line clear," but remained at "train on line;" and this, it is admitted, did not authorize the train to be sent on from No. 1 signal-box. The train arrived at No. 1 signal-box at 8.55. At about 8.56 Hovey again gave the "be ready" signal for the same up train, and this was replied to by Hill, giving, as he says, six beats at 8.57, but according to Hovey he received seven bells at 8.59; and this being a "strange" signal to "Hovey," he turned to the card on which the North London "Instructions for Working Block Telegraph and Out-door Signals" are hung up in the signal-box, and found that seven beats indicated "permissive block." He says he had not time to read the instructions, and he took the signal (seven beats) to mean that he was to work the train forward on the "permissive block" system, under which a train may proceed with caution, as followed on the Great Northern Railway, and accordingly he showed a green flag out of the window of his signal-box, took off the advanced starting-signal, and the train proceeded towards the junction. At 9.4 another train (the 8.58 a.m. from Finsbury Park) drew up and stopped at his up home-signal, and Hovey states that he sent the "be ready" signal forward again to Canonbury junction signal-box, which signal, was also acknowledged by seven beats. He took off his home-signal for the train to draw up to the advanced starting-signal, exhibited a green flag out of the window of his box, at which he stood and called out to the driver "go at caution" at 9.5, and pulled off the starting-signal, and this train then went on. This was the second train so sent forward. At 9.7 a.m. another train (the third) arrived from Finsbury Park, and Hovey says he went through the same process, and applied for the road at 9.10 a.m. for that train, being five minutes after the previous train had started, and he again received seven beats from Canonbury junction; that he put a green flag outside the window and called out to the driver of the train, and the train proceeded. At 9.10, after the third train had left, Hovey received another "be ready" from No. 4 Finsbury Park box, and a train (the 9.8 a.m.) stopped outside his box at 9.13. Then he again applied to Canonbury junction for the road, and again received seven bells. No change in the needle or indicator had been made on the face of the instrument up to this time. Hovey says that he once more pulled off his home-signal, placed his green flag out of the window, pulled off the starting-signal, and returned to the window in time to motion to the driver and to wave his flag. This was the last of the four trains. I should here state that this witness was not enabled to tell me whether the up distant-signal worked from the Canonbury junction signal-box was taken off for any of these four trains when he lowered the starting-signal for them to proceed, and I have already called attention to the difference in the statements of the two signalmen, Hovey and Hill, as regards the number of beats which were given from the Canonbury junction for the first train. Signalman Hill says six, and that he gave the same number of beats on to Highbury. This is confirmed by the Highbury signalman, but Hovey represents that he received seven for the first train as well as for the three subsequent trains. Now seven beats in the Great Northern regulations hung up in the same signal-box, signifies "stop train, obstruction of the line." There is another serious difference between the statements of these men which cannot be reconciled. "Hill" states that his six and seven beats were not acknowledged from No. 1 signal-box by the repetition of a similar number of beats; while Hovey says that he repeated the seven beats on each occasion. The register boy Long, in the Canonbury junction box, states that he did not hear them. Hovey's statement that he exhibited a green flag out of the window of his signal-box and cautioned three out of the four drivers of the four trains by word of mouth or by signal is entirely unsupported by any other testimony, and is directly contradicted by the statements of the four drivers, three firemen, and six guards of those four trains. On the other hand, the whole of these men all distinctly state that the up distant-signal worked from the Canonbury junction signal-box was lowered for each train, as well as the advanced starting-signal worked from No. 1 Great Northern signal-box, and the lowering of this signal could certainly not have been effected by the signalman in the Canonbury junction signal-box, inasmuch as the up distant-signal is locked by the trailing-points at the junction of this up line with the up line of No. 1 North London line when set right for a train from Chalk Farm, unless he had, immediately after the Chalk Farm train had gone on to Canonbury station, shifted the points and pulled over the lever, and had done the same when he sent forward the down train at 8.56. The first train from Barnet, appointed to leave Finsbury Park at 8.53, it is stated, on entering the tunnel was travelling very slowly. The driver found the up home repeater at "danger," and he ran steadily past it and stopped at the up home signal just outside of the south end of the tunnel at 9.2 a.m., and remained there about seven minutes, when he was signalled forward by green flag by the Canonbury junction signalman Hill, and he was on the point of starting when the rear of his train was run into by the engine of the second train, which had been sent forward by Hovey. The second train, 8.58 a.m. from Finsbury Park, on entering the tunnel is said by the driver to have been running at the rate of six or eight miles an hour, and he found, when he was three or four yards from it, that the up home repeater was on at "danger" against him, and he whistled and applied the brakes; and he next saw a red light at the tail of the first train, and his engine struck the train while travelling at the rate of two miles an hour. No damage to the first train was caused by this first collision, which took place at 9.5 according to

Hill, about 9 6 according to the guard of the train, and at 9.10 according to the driver of the train. The guard of this train, Henry Catherall, after the collision had taken place with the first train, was in the act of getting out of his van, as his own train started ahead, when another train came up and ran into his own train. He did not hear any whistle from the coming train before the second collision took place, and he thinks the steam was not on, as the train was not travelling fast enough. That he was making his way to No. 1 signal-box, and showed a red light towards the train which was approaching, but he doubted whether his lamp could be seen, as the tunnel was full of steam and smoke. He thinks the coming train was travelling at the rate of ten miles an hour. That he heard a crash, but could not say what damage was done to his own train. A down train passed towards Finsbury Park at this time. He continued to go back, and came against a carriage door, that was open, of the train which had run into his own train, and the passengers on seeing his lamp called out to him, and he told them to get out of the carriages and stand against the wall of the tunnel outside the down line. That he continued to go back, and had got about three carriage lengths past the brake-van of the train which had run into his own train when he became aware that another train was approaching. That he was just on the curve in the tunnel, but he did not know whether he had passed the repeater of the up home-signal; and as soon as he saw the train coming he took a fog-signal out of his pocket and placed it on the rails, and after he had put down the fog-signal he caught his foot in one of the sleepers, and fell down full length in the four-foot, in front of the coming train, and he managed to roll out of the four-foot, into the six-foot space just as the train passed him. His lamp was extinguished. He saw the guard (West, who was killed) of the third train, who was lighting his lamp, when he made him aware that he was going back to No. 1 signal - box. That after the fog-signal had exploded, he made his way to the north end of the tunnel, as well as he could in the dark, and threw up his arms and tried to attract the attention of the signalman in No. 1 box. He saw him come to the window then, but he still kept on running. When he got under the long bridge he saw that the advanced starting-signal from No. 1 box was still off, as well as the up distant-signal. He could hear another train coming from Finsbury Park, and he called out to the signalman to stop it, who told him that he had done so. When he was told this he was past the advanced starting signal and close to the box, and he went into the box and told the signalman what had happened; but he did not put up his advanced starting-signal to "danger" until he got into the box, and again called out to him. He did not see it put up to "danger," and does not know whether it was put up to "danger or not. This man deserves great credit for what he did, and he appears to have had a very narrow escape from losing his life. Another up train from Finsbury Park pulled up at the main-signal as he was getting there. It stopped at the main-signal. He thinks there was not more that two minutes interval between the second and third collisions. The driver of the third train states that his train (the train from Enfield) due to start from Finsbury Park at 9.3, left at 9.6 or three minutes late, and it was stopped by the advanced starting-signal from No. 1 signal-box for about a minute, and then both the starting-signal and the up distant-signal worked from Canonbury junction both fell together; that they were running about two or three miles an hour (the fireman named ten miles an hour) when they entered the tunnel, with the steam on at the time, and he ran forward until he saw the up home repeater on at "danger," and he whistled to draw the guards' attention and applied the steam-brake on the engine, and he saw nothing more until the collision occurred at 9.10 or 9.11, when he was running at about eight miles an hour. The driver of the fourth train (9.8 from Finsbury Park) says he found the up distant-signal worked from No. 1 signal-box was on as he passed it, but the up-home signal and up starting-signal worked from the No. 1 signal-box and the up distant-signal worked from the Canonbury junction box were all off as he passed them; that he received no caution signal whatever, neither was he spoken to, and when he entered the tunnel he was running at the rate of about twenty miles an hour with the steam off; he found the up home repeater on, and he whistled for the signal to be taken off; that he was on the look-out, but saw no tail lights on the train in front, and he could not see on account of the steam and smoke in the tunnel. He did not put on the steam brake or continuous brake, and was still running at the rate of twenty miles an hour when the collision took place. The engine of this train was thrown off the rails and much damaged. The men in charge of these trains all state distinctly that they received no caution signals of any kind at No. 1 signal box, as is usual when the traffic is being worked on the "permissive block" system, and tha the advanced starting and up distant dignal worked from Canonbury junction were either off when they first saw them, or were taken off for them to proceed. There is a strange uniformity in the evidence of the engine-drivers, firemen, and guards of each of the four trains as to the fact of their having seen the up distant-signal worked from the Canonbury junction off, as well as the up starting-signal worked from No. 1 signal-box, when the several trains passed it; and the fact of there not being any snow on the up starting-signal worked from No. 1 signal-box, as noticed by Mr. Shallis, while the arm of the up distant-signal worked from the Canonbury junction did not appear to have been sufficiently frequently moved to throw off the snow on it, is calculated to throw considerable doubt as to whether it had been lowered on each

occasion, when it is tolerably certain that it could not have been moved by the signalman in the Canonbury Junction. The whole of these trains were fully fitted with brakes, and the only surprising thing is that far more damage was not done by the three collisions, as, owing to the sharp curve in the tunnel, the tail lights of the several trains could not have been seen, if the tunnel had been clear of steam and smoke, at a greater distance than about 80 yards, as ascertained by actual experiment. In reference to the construction put upon the term "permissive block" by signalman "Hovey," I may remark that Clause 7 is very definite and distinct as regards the use of the Obstruction Signal Seven, as it says:—"7. Before a train is allowed to leave any siding, permission must be obtained from the signalman in charge, who must first telegraph the Obstruction Signal Seven to the next signal station in the rear of the siding, or, in the event of its being necessary to cross over to the other line, to the next signal stations in the rear in both directions, and obtain an acknowledgment of Seven beats." Hovey could not know in No. 1 signal-box whether Hill required to let a train out of a siding, or to cross a train to the other line near Canonbury junction. Again, seven beats is not to be found in any other clause of these instructions, and if Hovey did as he states he did, repeat these seven beats back to signalman Hill, at the Canonbury junction box, the latter would have had a perfect right to conclude that his signals had been properly understood by the signalman at No. 1 signal-box, and that he might have proceeded without any risk, had he required to do so, to let any train come out that was in a siding, or to shift a train from one line to the other without danger. Hovey had been previously employed no less than on 18 different days during the years 1880 and 1881 in this No. 1 Great Northern signal-box, and surely that should have been a sufficiently long time for him to have made himself acquainted with the mode of working prescribed in the instructions; and if there was anything in those instructions which he did not understand, he should have asked for explanations from the signal inspector or from a regular signalman usually employed in that box. As regards the not having time to read the Clause 7, it would not have occupied half a minute to have read it carefully through; and Hovey had no right whatever to have departed from the strict letter of the North London instructions for the block working and out-door signals. There is not a syllable in these instructions which points out or prescribes how the "permissive block" is to be worked; it is not recognized on the North London Railway, nor on the Great Northern Railway except under exceptional circumstances, for passenger traffic, as explained by Mr. Piggott, and on goods and mineral lines. Under these circumstances I can have no hesitation in saying that these three collisions in the Canonbury tunnel were the direct result of the unauthorized mode of working the four passenger trains introduced by signalman Hovey. This man made a great mistake. I do not think it can be contended by any one that when a signalman does not on the instant make out what a signal is intended to convey, he is at once justified, and without waiting to read carefully the instructions placed in his signal box for his guidance, in introducing a mode of working which is not specified in those instructions, merely because he has used them elsewhere, under different circumstances, where that kind of working is sanctioned. I am quite prepared to admit that signalman Hill need not have sent either six or seven beats, as the ordinary needles or indicators on the telegraphic instruments should have been sufficient to show Hovey that the line was not clear, and that trains should not have been sent on, but it was virtually only adopting an additional caution to make the line safe, which, however, would have been better carried out by six rather than by seven beats. Hill gives us his reason for sending seven beats on three out of the four occasions on which he transmitted them, that the line had been previously blocked from Canonbury station, and because he had received the two warning signals "Be ready" together. I recommend that seven beats "permissive block," be struck out of the North London Instructions. Both of these signalmen are described as being very good men. Hill (a North London signalman) has a clean sheet with nothing whatever recorded against him during his four years' service, and eight bonuses have been awarded to him for signalling without any report against him; and Hovey during a much longer service of eleven years has earned no less than twenty-three half-yearly bonuses for signalling without any report against him, but he has twice been fined; the first time in December, 1880, for "causing detention to a train," and the second time in February, 1881, for "giving 'line clear' before having first satisfied himself that a goods van which was being shunted was quite clear." The up home repeating-signal should be placed a few yards farther northwards, so as to be on the straight portion of the line. Speaking telegraphic instruments should be supplied to each signal-box. I am unable to afford any satisfactory explanation with reference to what is stated to have been the working of the up distant-signal from Canonbury Junction. It is said to have either been off, or to have been taken off for each of the four trains, while the signalman Hill's statement is clear and distinct that he did not take it off for either of them. It is possible that after the second collision some of the *debris* of the carriages might have fallen upon the wire, and thus pulled it off; but that would not have affected the signals exhibited to the first trains. Again, it has been suggested that something may have gone wrong with the working on the same post of the two slotted signals, so that the pulling off of the up starting-signal by the signalman in No. 1 signal-box, might have also drawn off the up distant-signal; but I could see nothing at the post to warrant this supposition. It is true that I think the slotting as now carried out should be done away with, but it would undoubtedly increase the chances of safe working in this tunnel if the up distant-signal locked the advanced up starting-signal worked from No. 1 signal-box at danger. In conclusion, I may state that I have received various suggestions, that had the electrical and out-of-doors signals been interlocked with each other, and that it should not have been possible for the up starting-signal worked from No. 1 signal-box to have been taken off without the consent of the signalman in the Canonbury Junction signal-box by one of the various systems now in use, these collisions would not have happened. But that is not so; for wherever the "permissive block" system is introduced, trains are frequently signalled forward by hand-signals while the home-signals still stand at "danger." Permissive block working should not be allowed on any lines where the traffic is heavy, and with very short intervals of time between the trains.

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QUALITY OF STEEL FOR TYRES AND AXLES.

WE reprint an interesting paper read before the Institution of Civil Engineers upon the subject of experiments made by Mr. Baker, a member of that Institution, in respect of the quality of steel used for tyres and axles. The writer deals with this important matter in a very practical manner. The travelling public as well as our engineers and users will be much pleased at having obtained reliable data with regard to the steel required for railway tyres, axles, and marine cranks. The elaborate tables relating to iron and steel, translated from the report of the Technical Committee of the German Union, which we are publishing from month to month, have thrown much useful light on this subject. It is well known that there are many qualities of steel; but since the introduction of Bessemer Steel, it is somewhat doubtful which quality is sent out of a manufactory, especially when there are several classes made on the premises. Consequently, it is difficult to know whether Bessemer or cast steel has been used until a breakage occurs, and then the mistake is found out at the cost, perhaps, of life and limb. We think it is essential that specified tests should be settled upon by the Institution of Civil Engineers, these tests to be of the highest class. The various steel makers should be asked to give the Council their ideas with regard to the best tests that can be obtained in every day work; and, after the tests have been thus determined, no engineer ordering material should allow any deviation from them. Such a course will bring to the front a good, *reliable* material. Unity as regards a scale of tests has been wanting amongst engineers, but after the amount of experience gained during the past decade, data founded upon practice should be welcomed. Those responsible would then have a guide for ordering materials on the quality of which the safety of many thousands of human lives depends.

For rails, Bessemer Steel is all that can be desired, but for tyres and axles experience appears to indicate that cast steel of the highest standard gives a far greater degree of security. Any extra expense to the railway companies is trifling in comparison to the dangers incurred by failure, or the pecuniary loss caused by engines and carriages frequently remaining idle whilst their tyres are re-turned. In the case of marine shafts a breakage on the ocean entails such dangers that no excuse can be made for any one ordering for this class of work material that is not the very best that can be produced.

"STEEL FOR TYRES AND AXLES."

By Benjamin Baker, M. Inst. C.E.*

THE present experience with reference to the use of steel in tyres and axles is so great that it might not unreasonably have been assumed that, by common consent, engineers and manufacturers would have arrived at certain definite qualities for these purposes respectiv ely To ascertain whether this was so, the Author recently obtained half-a-dozen pairs of tyres and axles from as many of the leading makers at home and abroad, and submitted the same to the tests briefly detailed hereafter. No particular mode of manufacture was specified, nor were any conditions imposed as to price.

The results were startling and unsatisfactory. Not only

* Read before the Institution of Civil Engineers.

was there no uniformity in the quality of steel supplied by the several makers, but even the two tyres of the same maker, as a rule, differed widely in behaviour under test. Thus the tensile strength of the steel in the twelve tyres ranged from 32.25 tons to 49.5 tons per square inch, and the extension from 5 per cent. to 25 per cent., whilst under the "drop test" one tyre might fail at the second blow of a weight of 1 ton falling 10 ft., and the next only do so at the twelfth blow from the increased height of 30 ft., the respective bendings before fracture varying from no less than $^9/_{16}$ in. to 28 in. in the 3-ft. tyre.

Similarly the tensile strength of the steel in the axles ranged from 27.35 tons to 40.7 tons per square inch, the extension from 17.6 per cent. to 23 per cent., and the number of blows sustained before fracture from 3 to 35. It will be seen hereafter that a high rate of elongation affords no guarantee that a tyre or axle will behave well under the drop-test, and probably no efficient substitute could be found for the rough and ready test of endurance afforded by the bending and straightening blows of a weight of 1 ton falling 20 or 30 ft.

Tyres.

The tests applied were :—

(1) A steady bending pressure, to ascertain the elastic resistance of the tyre to collapse.

(2) Successive blows from a weight of 1 ton falling 5, 10, 15, 20, 25, and 30 ft., to determine the endurance of the tyre under shocks and blows.

(3) A steady pulling stress to ascertain the ultimate tensile strength and elongation of samples of steel cut from the tyres.

The tests were conducted in all instances either by the Author, or by Professor Kennedy, M. Inst. C.E.

The tyres were of ordinary cross section, and weighed on the average 427 lbs. each. The two samples of the several makers are referred to as a_1 and a_2, b_1 and b_2, &c., in the ensuing Table.

—	Approximate elastic resistance to collapse.	Permanent Set under 40 Tons.	Ultimate Tensile Strength	Percentage of Elongation in Length of 5 Inches.	Extent of Bending under Falling Weight.		
					After 3rd Blow.	After 5th Blow.	After 8th Blow.
		Inches.	Tons per Sq. Inch.	Per cent.	Inches.	Inches.	Inches.
a_1	38 tons	0.05	49.50	14.0	$2\frac{3}{4}$	$6\frac{7}{8}$	$13\frac{7}{8}$
a	not taken	...	49.48	14.0	$2\frac{3}{4}$	$6\frac{5}{8}$	$13\frac{7}{8}$
b_1	38 tons	0.05	46.43	18.6	3	$7^9/_{16}$	$15\frac{3}{8}$
b_2	not taken	...	40.9	23.6	3	$7\frac{1}{2}$	$15\frac{3}{8}$
c_1	,,	...	44.21	8.0	$3^9/_{16}$	broke at 4th	...
c_2	36 tons	0.07	42.48	5.0	$4\frac{1}{8}$	broke	...
d	not taken	...	42.51	19.6	broke	...	...
d_2	33 tons	0.18	37.36	5.8	broke at 2nd	...	...
e_1	36 ,,	0.05	38.85	24.4	$3\frac{3}{4}$	broke	...
e_2	not taken	...	38.01	25.0	4	$10\frac{1}{8}$	$20\frac{3}{8}$
f	,,	...	34.67	14.5	$5^5/_{16}$	broke	...
f_2	29 tons	0.60	32.25	12.0	$5\frac{1}{8}$	$11\frac{7}{8}$	$24\frac{3}{8}$

Note.—The moment of resistance of the tyre being 5, the bending moment 5 W, and the average elastic tensile resistance of the steel 22 tons, the elastic resistance to collapse might have been wrongly calculated to be 22 tons also; but for reasons set forth in the Author's Paper on "The Practical Strength of Beams,"† it would have been more correctly assumed at about 22 tons × 1.7 = 37 tons.

Axles.

The tests applied were :—

1. Successive bending and straightening blows from a weight of 1 ton falling 5, 10, 15 and 20 feet, and continued at the latter height until failure occurred. The axles were placed on solid bearings 3 feet apart, and were turned half round after each blow.

2. A steady pulling stress to ascertain the ultimate tensile strength and elongation of samples of steel cut from the axles.

The axles were nominally 4 in. in diameter, but ranged from that figure to nearly $4\frac{1}{4}$ in. The makers are referred to under the same letters as in the previous table.

—	Diam. of Axle.	Ultimate Tensile Strength.	Percentage of Elongation in Length of 5 Inches.	Extent of Bending under Falling Weight.		Number of Blows Causing Failure.
				10 ft.	20 Feet.	
	Inches.	Tons per Square In.	Per cent.		Inches. Inches.	
a	4	27·79	22·0	$2\frac{7}{8}$	$4\frac{3}{4}$ to $5\frac{5}{8}$	35
b	$4\frac{1}{4}$	40·7	20·6	$1\frac{5}{8}$	$3\frac{3}{8}$	8
c	$4\frac{1}{8}$	36·85	22·0	$2\frac{1}{2}$	broke at 15 ft.	4
d	$4^1/_{16}$	27·35	23·0	3	Inches. Inches. $4\frac{5}{8}$ to $5\frac{7}{8}$	34
e	$4^1/_{16}$	31·15	19·4	$2\frac{7}{8}$	$4\frac{3}{8}$	14
f	$4\frac{1}{8}$	32·34	17·6	$2\frac{3}{8}$	$3\frac{5}{8}$	6

Comparing the above with the previous table the following conclusions would appear to result :—

1. Maker *a* adopted for his tyres a steel of high tensile resistance, uniform in quality, with a medium amount of elongation, and capable of standing several blows from one ton weight falling from the full height of 30 ft. For his axles he used very mild steel, having 43 per cent. less tensile resistance and 50 per cent. more elongation than the tyre steel, and of great endurance under the drop-test.

2. Maker *b* apparently preferred a medium quality of steel for both tyres and axles, and as a consequence his tyres were not so hard and strong as the *a* tyres, and presumably not so durable, whilst his axles were much harder, and failed with comparatively few blows under the drop-test.

3. Maker *c* supplied a couple of moderately hard tyres, but the steel had a dangerously low rate of elongation, and failure quickly resulted under the drop-test. The axle was somewhat softer than the tyres, and had a satisfactory rate of elongation, but signally failed to withstand the shock of the falling weight.

4. Maker *d* used a fairly hard but very untrustworthy quality

† *Vide* Minutes of Proceedings Inst. C.E., Vol. LXVII., p. 251.

of steel for his tyres, as evidenced by the wide difference in the ultimate strength and elongation of the two tyres, and by the snapping of both with a slight blow under the drop-test. His axle, on the other hand, was of mild steel of suitable tensile strength and elongation, and behaved exceptionally well under the drop-test.

5. Maker *e*, though his tyre steel was of uniform tensile strength and elongation, did not succeed in securing uniformity of quality. Although the steel was too soft for good wearing purposes, and had a high rate of elongation, one of the tyres failed with half the number of blows that the second and several other much harder tyres sustained. The axle was somewhat hard, and suffered correspondingly under the drop-test.

6. Maker *f*, like maker *b*, apparently used the same steel for both tyres and axles, but of a much milder quality. Notwithstanding its softness, the steel did not prove uniform and trustworthy, as the axle broke at the sixth blow with a bending of $3\frac{5}{8}$ inches, whilst one tyre bent $27\frac{7}{8}$ inches before fracture, and the other only $8\frac{5}{8}$ inches.

It may be interesting to remark that samples of steel from axles supplied in 1868 by maker *a*, and in 1862 by maker *b*, were tested by Herr A. Wöhler in his celebrated series of experiments on the "fatigue of metals."* At the dates named it may be inferred that the former maker was in the habit of supplying steel for axles having a tensile strength of from 26 to 29 tons per square inch, with a rate of elongation of from 16 to 20 per cent., and the latter maker steel having what would now be considered in the case of axles the dangerously high tensile resistance of from 48 to 50 tons with an elongation of from 11 to 18 per cent.

The conclusion the Author draws from his experiments is, that it would be imprudent, on the part of an engineer, to leave the quality of steel either for tyres or axles to the discretion of a manufacturer, or to forego the most rigid system of inspection. An occasional test is of little use, because the most inferior materials may at times accidentally produce a good result; but to ensure a good result and perfect uniformity in quality the best materials and the greatest care in manufacture are absolutely essential. The tabular results show that a sample of steel may be cut from a tyre or axle and be tested with perfectly satisfactory results as regards tensile strength and elongation, and yet that the tyre as a whole may fail under moderate shocks, either on account of the steel being inferior in some repect, which those tests do not detect, or from its not being uniform in quality throughout. Similarly as regards the axles. Mildness, great elongation, and an ability to withstand the "temper" test, do not always ensure the steel being able to withstand the shocks and jars of traffic. Half-a-dozen specimens may be cut for testing from a given axle, and yet some weak spot in it escape notice. It has been frequently proved, both by chemical analysis and by physical tests, that a bad ingot, or a steel rail rolled from it, differs widely in composition and strength from point to point, and the same holds good with a bad steel axle. A severe blow, either under the drop-test or in actual working tries every part of the tyre or axle, and finds out the weak spot, if there be one, whereas by almost any other test there would be a chance of the fault remaining undetected.

Assuming the steel to be of good materials and to be uniform in quality, it remains to be decided what degree of hardness is most desirable in the case of tyres and axles. Experience has proved that steel, having a tensile strength as high as fifty tons per square inch, is quite trustworthy for use in tyres in ordinary climates if the tyres will stand a proper drop-test. Similarly, experience in ship-building yards and elsewhere has led to the specification of mild steel having a tensile strength of from twenty-six tons to thirty-two tons per square inch, that quality being found best able to sustain without injury the contingencies of working. Probably a limit of forty-six tons to fifty tons in the case of tyres, and of twenty-seven tons to thirty tons in that of axles, with proper drop-tests, would, on the whole, be the best to specify in order to secure the most suitable steel for the respective purposes.

* *Vide* Über die festigkeitsversuche mit eisen und stahl. Berlin, 1870.

The London and Suburban Railway Official's Association.—On the 18th ultimo, the Annual Dinner of the members and friends of this useful Association was given at the Criterion, Mr. Kirtley, Locomotive Superintendent of the London, Chatham and Dover Railway, took the chair, Mr. William Beattie, Assistant Locomotive Superintendent of the London and South Western Railway, occupying the vice-chair. Among those present were Mr. Tomlinson, Mr. W. B. Rickman, Mr. J. Stirling, Mr. J. Knight, Mr. G. Spencer, Mr. Priestly, Mr. G. Sadler, Mr. W. J. Anwell, Mr. J. Kenworthy, Mr. R. Stockdill (Secretary), Mr. W. Tofield, Mr. Wilkinson, Mr. Lane, Mr. Bradshaw, Mr. Stewart, Mr. Burnett, Mr. Cookson, Mr. Gwynn, Mr. Osmund Gibson, Mr. Lawrence Saunders, Mr. Eveleigh, Mr. Gray, Mr. Levett, Captain Davis, Mr. Carlton, Mr. Hunt, Mr. Davey, Mr. Newton, and a large number of gentlemen representing various departments of railway work. The Chairman announced the continued prosperity of the Association, and the usual toasts were proposed and seconded.

LIGHT RAILWAYS.

BELPAIRE'S STEAM CARRIAGE.

THIS carriage, represented at Plates CXLI. and CXLII., is designed for use on local lines where the journeys are short and numerous stoppages necessary, and may be regarded as a means of a locomotion intermediate between the tramway and a railway-train. The whole of the carriage and engine rests on three axles, and only one of these, the middle, is a driving-axle. As will be seen from the figures on Plate CXLI., the carriage-frame is divided into three compartments, viz., one for the first and second classes, the latter being separated from the former by a partition, the average height of a man, and each containing twelve places; a second for the third class, containing thirty-two places, and divided from the above by sliding doors, and lastly a compartment next the engine for the luggage, capable of holding about 10 cwt. Between the third class and the luggage compartment is a transverse passage with steps each side, for the entrance and exit of the third-class passengers. The first and second classes enter by means of steps from the rear platform. The forward axle has a lateral play of ·4 in., the rear axle has a longitudinal play of ·8 in., and a transverse play of 3·2 in. also, the driving axle being quite independent of the frame of the carriage, these arrangements allow of a free passage round curves of very small radius. As will be seen from Fig. 1, Plate CXLII., the double play of the rear axle is obtained by uniting the axle-boxes to the frame by means of connecting-rods jointed freely to the links carrying the springs. The wheels of each axle are acted on by a screw-brake. The elasticities of the springs per ton load are the following:—

Rear axle	2·5 in.
Forward axle	1·17 ,,
Middle axle	1·55 ,,

The engine frame, which is beneath the carriage (Fig. 2, Plate CXLII.), is united with the driving axle by means of two connecting-rods, *b*, terminated on the axle by the plummer blocks, *c*, and having on their opposite ends pistons, *p*, against the two faces of which press india rubber springs fixed in the cylinders, *d*, bolted to the frame.

These connecting-rods are of the same length as those attached to the piston-rod, consequently this arrangement maintains the driving-axle at practically the same distance from the steam cylinders, while it leaves the frame and the engine free to follow the movements of the springs. The engine and its frame may be easily detached from the carriage for inspection and repair.

Slide-motion.—The slide-motion adopted is that of the Walchaert's system. The bent rod, $A'A_1'$, connected to the piston-rod of the right hand cylinder, gives to the slide-valve of the left-hand cylinder a part of its motion, by means of the rod A′, b′, which works the link, *c′*; and also to the slide-valve of the right hand cylinder, a part of its motion by means of the rod, A′, d, fixed to the slide-rod by the forked-joint, f. In a similar manner the couplement of the motions of each valve is obtained from rod AA_1, fixed to the piston-rod of the left hand cylinder, viz., in the former case by means of the rod A, d′, fixed to the slide-rod by the forked-joint f′, and in the latter by means of the rod, A b, which works the link, *c*, connected to the slide-rod of the right-hand valve.

The reversing-motion is indicated by the letters p, m, and n.

We intend to describe and illustrate this motion more fully in our next month's issue.

Fig. 3 gives a view of the driving wheels and axle, the cranks being placed at right angles to each other. The parts of the mechanism to which we would draw attention as being peculiar to this engine, are the slide-bars, the form of the connecting-rod ends, and the inclined slide boxes.

The diameter of the cylinders, *d*, is 6·6 in., that of the driving wheels, D, 38·2 in., and the stroke of the pistons, C, 12·5 in., which gives for the modulus of traction $\frac{d^2 l}{D} = 664{\cdot}4$ lbs., and the mean tractional force $\cdot 65\ p \cdot \frac{d^2 l}{D} =$ 4312 lbs. The carriage carries a water tank of 40 c. ft., and coal-bunkers able to hold 12·8 c. ft. of fuel. We give below some of the principal items concerning this engine:

		Lbs.
Total maximum weight on driving axle ...		19,800
,, ,, ,, forward axle ...		22,000
,, ,, ,, rear axle ...		15,400
Total		57,200
Live load	total	5,280
	per passenger, about	94·6
Mean consumption per mile	water ...	88·6
	coal ...	17·6

Mean speed ... 15 to 20 miles per hour.

PAINTING OF LOCOMOTIVES.

THE following paper on this subject was written by Mr. J. M. Millard, and read at the last meeting of the Master Car Painters' Association, U.S :—

"In painting locomotives, the painter does not aim to get an elegant or lustrous finish, as in some other classes of painting, but has durability more particularly in view. Lustre in a locomotive can be gained for a short time only. Being out in all kinds of weather, rain or shine, the machinery in constant use, the paint put on must be elastic and durable, in order to resist to a certain extent hard usage. In painting a locomotive the painter encounters certain difficulties which have to be overcome; first is rust, second is grease. Rust may to a certain extent be prevented by scouring with sandstone and emery cloth, and applying a coat of boiled oil, wiping off with waste cotton. I govern myself according to the time there is to paint, and mix my paint accordingly. My experience is that boiled for iron, and raw oil for wood, is best, the wood being more absorptive. The wooden parts I prime with raw oil, lead, and a small quantity of drier; when dry, sand-paper down, cleanse, and apply a coat of oil lead, which dries with an egg-shell gloss. Putty on this coat, when dry, all nail holes and open grain; then sand-paper down and give a coat of dark lead. When well gone over and well puttied up, we are ready for the colour —two coats of drop black ground in japan, made elastic with raw oil. My experience is that greater trouble arises in not having the colour elastic as regards scaling and chipping than from any other cause, and I add enough oil to make it dry with an egg-shell gloss. The next coat is the colour and varnish. The safest plan is to grind the colour in the varnish, then add enough varnish to work freely and dry properly. After this colour and varnish is dry I letter; then give two coats of finishing varnish, allowing the necessary time for drying between the coats. The tank is done the same way, excepting that there are two coats of lead; then a coat of half lead and half metallic paint, ground in boiled oil, with a quantity of japan and turpentine; then putty up with a hard drying putty. I find that putty made with metallic paint and dry lead, works better than lead and oil, and holds better on iron work. The next coat is the same as the preceding one, but with less oil, made to dry firmly; then two coats of roughstuff. These two coats are rubbed with lump pumice-stone. The idea is to gain a level surface on the iron, and we have got to rub to get it. Two coats of colour made elastic with oil, and two coats of engine finishing varnish—no rubbing varnish except what is in the colour and varnish, because it is not necessary to insure durability. The minor parts, such as the trucks, I give a coat of dark lead colour or lamp-black. A coat of drop black and a coat of colour and varnish made with a finishing varnish are enough for these parts. The drivers' dome and sand-box may be painted, and the little odds and ends looked after, of which there are quite a number. The paints and varnishes should be put on with an aim to economy—no more put on than is necessary."

THE PROJECTION AND CONSTRUCTION OF RAILWAYS—COMMERCIALLY AND PRACTICALLY CONSIDERED.

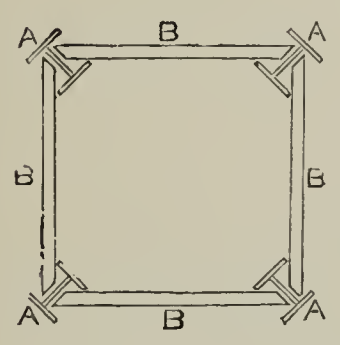
(*Continued from page* 39.)

ONE application of this test is not to be accepted as conclusive. After the first application the column should be removed and turned one quarter round, and again tested, this course being followed until the column has been four times tested; then, by the noted deflections, it will be found whether the column be of *uniform strength* in every direction, a condition which it seldom obtains unless columns *are cast vertically*.

The uncertainty of getting good castings (we say uncertainty, for there is no *real* difficulty, only a financial one; that of jobbery) has led engineers to consider the advisability of adopting wrought-iron as a material for the columns of bridge and viaduct piers. Such piers have for many years been used in America, but the first, and, as far as we know, the only, example of the use of that material for viaducts of considerable elevation, is to be found in the Halesowen Viaduct.

In this viaduct, carrying a single line of railway, each pier consists of four H irons, arranged, as shown in Fig. 15.

FIG. 15



A,A,A,A, are the four H-iron columns, connected by bracings, *B,B,B,B.* There is some apparent awkwardness in these diagonal connections, but being properly designed, perfect stability is secured.

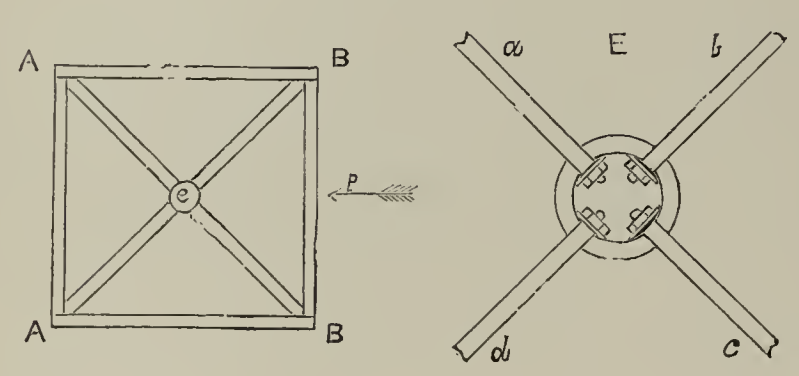
The diagonal bracings consist of round bars passing through a central ring and tightened up by nuts, in order to secure uniform strain upon all the bars.

This is a favourable opportunity to caution the young engineer against the fallacy of adopting the *practice* of putting "initial strain" upon bracings, or indeed upon any part of a structure; and upon this point so much stress has been laid by both *pseudo-mathematicians,* and *rule of thumb engineers,* that it is really worth a little common-sense consideration.

Now it stands to reason that no benefit can accrue from putting upon any structure a strain *greater* than that which it should naturally sustain; hence, if "initial strain" is to be of any use it must be *contrary to the strain brought upon the structure by its normal load.* Thus, for instance, if we can construct a suspension chain with "initial strain" in compression, or an arch with "initial strain" in tension, there might be something to gain, but this evidently cannot be done.

We will now consided the case of cross bracing such as that shown in Fig. 16. The columns, AA and BB are horizontally

FIG. 16



braced by the bars AB, AB, and diagonally by the system of round rods, *a,b,c,d,* connected by bolts with the horizontal bracings, AB, AB, and with each other by a ring *e,* shown to a larger scale at E. Initial strain can be put upon these bars by over-tightening the nuts within the ring, those nuts taking upon the screwed ends of the bars, *a,b,c,d.*

The pier or framed structure is liable to stress from either side—hence it is evident that the initial strain upon one line of bracing may assist the normal strain upon the converse line of bracing. Thus, for instance, we will assume a wind pressure acting in the direction of the arrow, P, and also that the lines of bracing, *ac, bd,* are under initial tension, then it is evident that the wind pressure will tend to increase the tension upon *ac,* and in this *it will be helped by the initial tension on bd.*

What is really required is a fair steady bearing. So soon as the parts of any structure are in solid contact, no good can be done by straining the elements of such structure, for, except such strains as are produced by passing, or permanent loads, the elements of the structure should be at rest.

In this connection we may show how necessary it is that the engineer should have a more than superficial knowledge of the materials with which he has to deal, especially in the case of ironwork.

A bar under initial tension will gradually lose that initial tension—a kind of "tiring" of the metal will occur—but regarding this alteration in a scientific light, the action, which is inter-molecular, becomes clear. If we take any body which is physically in a condition of molecular equilibrium, and permanently disturb that equilibrium beyond the limits of elasticity, the molecules will re-arrange themselves, and, so conforming to altered conditions, again find under those conditions a state of renewed normal equilibrium. This is most clearly shown in the ease with which the molecules of lead adjust themselves to alterations of form; and again in copper wire, which being forcibly stretched, seems to resume the range of elasticity it had before passing through the draw-plate.

Considering that the elasticity of commercial iron is not perfect, even under a strain of half-a-ton per sectional square inch, it is evident that if initial strain could be of any use it would soon be lost.

The most ridiculous way in which initial strain can be applied is in the over-tightening of bolts and nuts; when the bolt-head and the nut take their fair solid bearing nothing more can be done, but some ignorant labourers persist in using long spanners until they wrench the threads of both bolts and nuts in such a manner as to practically destroy their strength, and in no case has this been more clearly illustrated than in that of a cast-iron bridge constructed some twenty years since, in the North of England, to carry a railway over a river. An over-zealous inspector tightened up the nuts with a long spanner, upon the end of which he leaned his whole weight. When the test load of heavy engines (which we believe had also steam tenders of the Sturrock type attached to them) came upon the bridge, the nuts, weakened by the initial strain, gave way, and, to use the words of a bystander, "flew about like bullets." However, the bridge being a simple arch, no accident resulted, and after certain alterations were made, the Board of Trade sanctioned the opening of the line of which it formed a part.

We will now return to the Halesowen Viaduct, to explain the form of the bed-plates for the H-iron columns (the writer of these articles having designed the details and drawn the specification for them, has at hand the necessary information), which supply the place of the *bases* of cast-iron columns.

The specification was as follows:—

"The bed-plate is of cast iron, 3 ft. 9 in. square, its general thickness is 2 in., it is strengthened by eight ribs, each being 2 in. wide and 1 in. high. On the bed-plate, and in one piece with it, is cast a socket 12 in. in height from the bottom

of the bed-plate, the metal being $1\frac{1}{2}$ in. in thickness, and the socket so formed as to admit of the insertion of the foot of the H-iron, leaving all round it a space $\frac{1}{2}$ in. wide to be filled in with *iron cement* caulked, so as solidly to join the H-iron to the base or bed-plate."

The use of iron cement is to make the base-plate, as it were, a solid piece with the H-iron column, and this it will do if the cement is properly mixed. We have seen cases in which it has been used for cast-iron joints, where, after a few years, upon its becoming necessary to open these joints, the metal came away in a skin *upon the cement*, with both cement and metal good, but, we should add, that was twenty-five years since, and, therefore, before the *general* use of "*beaumonteague*."

In regard to the clear width between parapets of bridges *under* the railway there should never be less than 4 ft. 6 in. clear from the outside rail to the inside of the parapet, thus giving 14 ft. clear width for a single line of railway and 25 ft. for a double line.

These widths meet the Board of Trade requirements, with a few inches to spare, but in the case of a viaduct, if limited to these widths, recesses or refuges must be provided at intervals, similar to those previously described in connection with tunnels. In the construction of stone or brick viaducts of any magnitude great care should be taken to ensure the solidity of the piers, and a system of through bonding from face to face adopted to avoid the possibility of the piers spliting.

FIG. 17

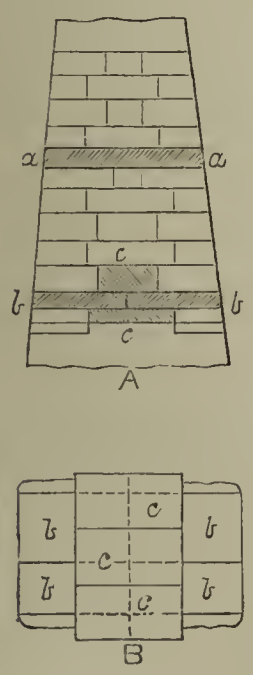


Fig. 17, A, shows a part vertical section of a pier with the through bonding stones shaded, at *a*, *a*; if the thickness is not too great to allow the bond being made by one stone in length, then of these a sufficient number should be laid side by side to cover the width of the pier; but where the pier is too thick to be bonded through by a single stone, another arrangement must be adopted, such as is shown at a lower joint. Here the bonding course consists of two sets of stones, *b*, *b*, meeting at the centre of the thickness of the pier and themselves tied by large stones, *c*, *c*, and in plan, *c*, *c* should laterally break joint with the stones, *b*, *b*, as shown at B.

In the construction of masonry viaducts of magnitude, there has to be considered not only the stability of the structure, *per se*, but also that of the ground upon which it is to be erected.

As a medium example of the load thus put upon a foundation, we will take the centre pier of a large viaduct, assuming the spans of the arches to be 40 ft., and the height of rail level at the centre 100 ft. above the level of the foundations. If the arches are semi-circular, and, say 2 ft. thick, then, allowing 2 ft. from the crown of the arch to rail level, the nett height of the pier will be $100 - [20 \times 2 \times 2] =$ 76 ft. Taking the batter of the piers to be $\frac{1}{4}$ in. per foot, and the pier to be 4 ft. thick at the springing, and 28 ft. wide, we have an average horizontal section of 163 square ft., hence the total quantity will be 12,388 cubic ft., weighing 719 tons, or about $3\frac{1}{3}$ tons per square foot of foundation area for pier. In addition to this, we have the weight of two half arches, and the live load amounting to 550 tons, or $2\frac{1}{2}$ tons per superficial foot of foundation area, being in all 5·84 tons per superficial foot.

The late Professor Rankine gave the following as safe loads on foundations:—"Rock, as hard as red brick, 9 tons; good concrete, 3 tons; soft rock, 1.8 tons; hard clay, 1 to 1.5 tons."

The writer of these articles has put 13 tons on rock and 9 tons per square foot on blue shale.

We here append a table of loads equivalent to a train of the heaviest Great Northern Railway engines, and these loads may also be taken for the data upon which to design iron bridges:—

Span in feet.	Load in tons.	Span in feet.	Load in tons.
16	31	60	90
18	32	65	98
20	37	70	105
22	41	75	113
24	45	80	119
26	48	85	125
28	50	90	133
30	53	95	140
32	54	100	145
34	56	105	153
36	58	110	161
38	60	115	169
40	63	120	175
42	66	125	183
44	68	130	190
46	71	135	198
48	73	140	205
50	78	145	212
55	83	150	219

We will now proceed to the consideration of bridges *over* the railway; and in this connection we must bear in mind that we do not only have to satisfy the requirements of the Railway Acts, but also the requirements of local magistrates and local Boards of Works. One of the most expensive details in connection with a new line of railway, if it rests in the magistrates' hands, is the stopping of a foot-path, and it has been found more economical in the long run to get a special act than to arrange with the local magistrates. There is a regulation under the Board of Trade not absolutely requiring a railway company to construct their bridges over the line of sufficient strength to carry a 20 ton traction engine but if any bridge fails under the load of a 20 ton traction

engine the Company is responsible for all damage that accrues therefrom.

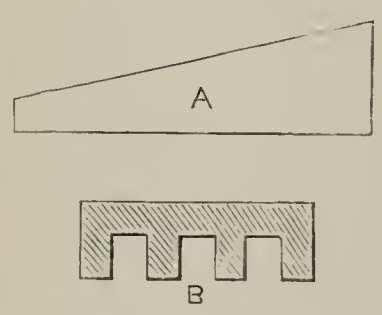
We here append the weights of traction engines manufactured by Fowler & Co., of Leeds :

Width over Wheels.		Weight on Hind Wheels.	Centres.		Total Weight.	
ft.	in.	Tons.	ft.	in.	Tons.	Cwt.
20 h.p....8	10	14	20 h.p....15	6	22	0
16 h.p....8	6	11	16 h.p....14	4	18	10
14 h.p....8	4	10	14 h.p....13	8	16	0
12 h.p....8	4	10	12 h.p....13	0	14	0
10 h.p....8	4	—	10 h.p....12	6	13	10
8 h.p....8	0	—	8 h.p....10	6	10	15
6 h.p....7	10	—	6 h.p.... 9	6	9	10

It will be seen from the foregoing table that the heaviest traction engine weighs 22 tons. We should, however, advise our young engineers to allow 25 tons for the weight of a traction engine ; and in cases where the roads are on a steep gradient, such, for instance, as 1 in 5, as occurred at Thiefscore Lane, near Bradford, the factor used in designing the girders should be 4 tons per sectional square inch, although the Board of Trade allow 5.

It must also be borne in mind, that iron girders on a gradient must have bed plates so arranged as to give a horizontal bearing, as shown at Fig. 18 A, being a side elevation, and B, a cross section ; for if the weight comes perpendicularly upon the piers or the abutments of a bridge the girders will not be likely to slip, and even with a heavy wagon or traction engine, if the brake is suddenly put on as it is going down hill, the accumulated work in such a mass might start a wrought-iron girder.

FIG. 18



We must again call attention to the necessity of ascertaining what water and gas pipes may be interfered with by the construction of a railway ; for it has on several occasions severely taxed the pockets of the proprietors to meet the claims thus made upon them by local landowners ; and in no case should we advise that either gas or water pipes be carried on brackets outside the girders of an iron bridge. Through a brick bridge a special arrangement may be made, but in no case should the pipes be permitted to penetrate the arch ; and when pipes are so carried, the joints should be always made spigot and faucet, and in no such case should flanged joints be made.

It is also necessary to consider the kind of roadway to be carried by a bridge over a railway. The load put upon such bridges frequently amounts to about two hundred lbs. per superficial foot, without including the necessary ballast upon which to bed the setts. These setts must be put "tooth upward" to satisfy the local surveyors ; and further we must provide for channels, or, as they call them in the North of England, kennels, to take the drainage from the footpaths ; for these channels, setts $4\frac{1}{2}$ in. deep will be sufficient, backed by a kerb 7 in. by $4\frac{1}{2}$ in.

The width of the path will depend upon the locality in which the bridge is situated, but in no case should flags less than 4 in. thick be used, and these should be set in hydraulic lime, which we have found to be more satisfactory than setting them in Portland cement, as the slightest settlement with that cement leads to rupture of the pavement.

A causeway 7 ft. 6 in. wide from the inside of the parapet to the outer edge of the kerb should have a fall of $2\frac{1}{2}$ in. It has been a common practice to give 3 in. fall for this width of causeway, and this amount of fall is not only unnecessary but may lead to accidents, and more especially in such localities as those in which orange peel may be thrown about.

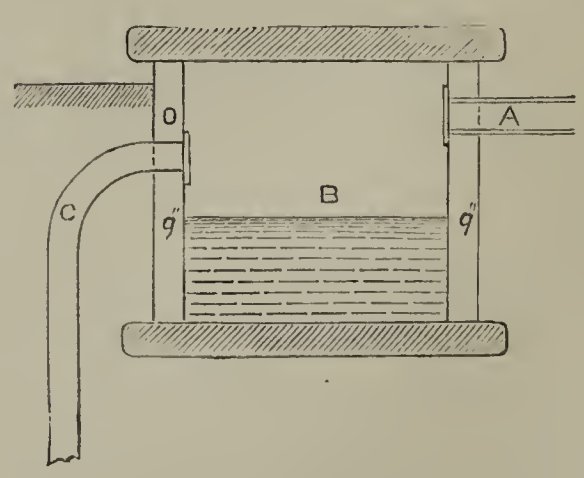
In the construction of bridges over a railway the parapets should be so arranged that it will be impossible for mischevious boys to climb upon them. A few years back a case came under our notice in which a stone thrown down from the parapet of a bridge fell through the blast-pipe of a locomotive engine and destroyed the slide valve of one of the cylinders ; hence 6ft. is the lowest height that should be allowed for the parapets of bridges over the railways, and in the case of iron bridges the parapets may be further protected by oak coping, armed with spikes or tenter hooks.

In some cases small streams have been carried under the railway through an inverted syphon, but such a course should not be adopted in a manufacturing district, because the detritus passing from dye works is liable to choke such a syphon ; and although various arrangements have been designed to obviate such a trouble, we are not aware of their having answered the purpose. And, moreover, there is the possibility of a dead cat or kitten being thrown into a stream leading to a syphon, such as that to which we have referred.

Where it is absolutely necessary to use a syphon, a cesspool should be made on the higher side of the railway, and this cesspool should be furnished with a verticle grating, made with bars $\frac{5}{8}$ in. square and a $\frac{1}{4}$ in. space between them, in order to prevent any obstructive matter from passing into the syphon.

The water coming in through a channel shown at A (Fig 19),

FIG. 19

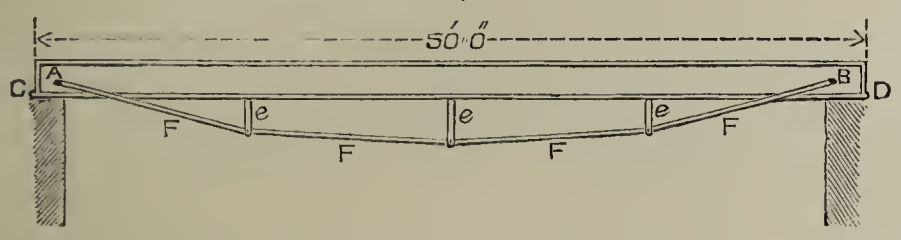


all sediment will settle at the bottom of the cesspool, where

indicated by B, the clear water passing away through the pipe, C, which has a flange holding it upon the side-wall, D. On the cover of the cesspool is a lid to permit of its being cleansed at such intervals as may be necessary.

There is one thing that must be particularly observed in the construction of these cesspools; it is, that all mortar and cement must be absolutely hydraulic to prevent the possibility of leakage; and that part of the cesspool through which the pipe, C, passes should be made of Staffordshire blue brick, and the pipe set in with iron cement, and in cases of any leakage, melted sulphur should be poured in. In some cases a stream can be carried over the cutting, as has been done in the neighbourhood of Ovenden, on the Halifax, Thornton and Keighley Railway, in which case, to save weight, a trough was made and supported by a suspension chain, as shown at Fig. 20, in which the trough, A B, is

FIG. 20



supported by suspension links, *F, F, F, F,* connected with the trough by struts, *e, e, e,* the suspension links being attached to the trough by bolts at *C* and *D*.

In every case in which it is necessary to use suspension links, we must be careful to make the eyes of such links equal in strength to the bolts or pins to which they are connected. We have found that the length of head of such links should be $1\frac{1}{2}$ diameter of the bolts, as shown in Fig. 21.

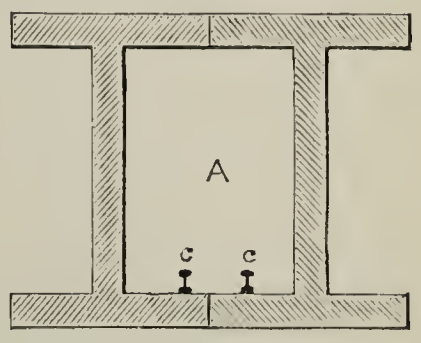
FIG. 21

In this connection we may refer to the various attempts have been made to construct a rigid suspension bridge. The most successful design is that made by Mr. Halliday Smith and successfully used in Brazil.

Mr. Ordish, one of the most experienced engineers in bridge work, designed a rigid suspension bridge, using in its construction cross-chains, and subsequently Mr. Thomas Page, the engineer of the Westminster Bridge, designed the Chelsea Suspension Bridge, stiffening the platform by lattice girders on each side of the roadway. After some time it was thought that the bridge was not sufficiently strong for the traffic that it had to carry, and therefore Mr. Edwin Clark was called in to report upon it. He reported the chains as somewhat too weak; but as the writer of these articles knows personally that the chains were tested to 12.5 tons per sectional square inch by the resident engineer, Mr Harrison Enoch Ayden, he thinks that the chains were originally sufficiently strong, and this is one case in which the specification has been faithfully insisted on.

In no case should we advise the construction of a tubular bridge to carry a railway; and if we look back to the history of such tubular bridges as have been constructed, we have sufficient evidence to support our views. We will take, for instance, the Britannia Tubular Bridge, over the Menai Straits. The first idea that Mr. Robert Stephenson had was to make two great cast-iron girders, as shown in Fig. 22, imagining that the train could be run upon the flanges of such cast-iron girders on rails, shown at *cc*, forming a tunnel, A. Under the advice of experienced mathematicians, Mr. Robert Stephenson determined to make a wrought-iron tubular bridge.

FIG. 22



He was either directed or mis-directed by the late Mr. George Bidder; and then constructed the first continuous girder bridge erected in England, after the late Sir William Fairbairn had tried experiments on models which he constructed at the Millwall Ironworks, in order to ascertain the practical strength of such structures. That the late Sir William Fairbairn had no credit for the Britannia Bridge is a stain upon English engineers, for it was Sir William Fairbairn who gave Robert Stephenson the information that enabled him to construct not only the Britannia Bridge, but also the Albert Bridge over the River St. Lawrence; and by the time he constructed that, he had found out that it was unnecessary to make a cellular bottom flange, as the bottom flange is in tension.

We may now call our reader's attention to the fact that the Albert Bridge above referred to was made without a celluar bottom flange, and, instead of being continuous throughou its length, was made in lengths of two spans, the bottom floor being stiffened by T-irons; but we hardly imagine that tubular bridges will in future be constructed to carry railways.

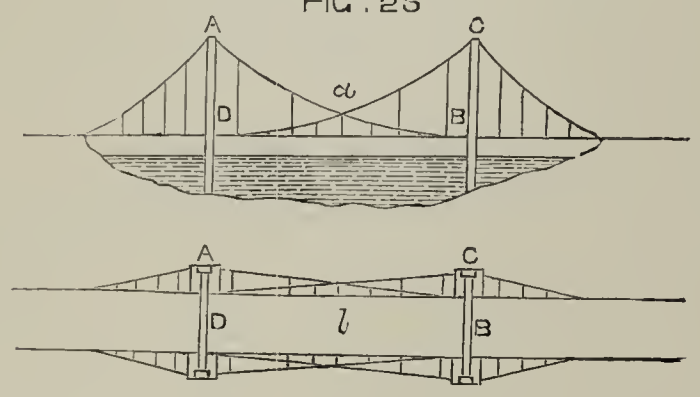
In South America trussed bridges carried upon wrought-iron columns, with cast-iron caps and bases, have been largely used, and in many instances such structures are more to be relied upon than those that we ordinarily use in England.

The trusses used in America are hardly such as we should recommend; they are usually all based upon the Harper's Ferry Bridge system, and if one rod fails the whole structure must fall.

We will now return to the suspension bridge invented by Mr. Halliday Smith. Instead of using continuous girders throughout the platform, discontinuous beams were used from shoe to shoe of the suspension rods. The suspension rods are carried by semi-chains, as shown in elevation at A (Fig. 23); and the structure is rendered more steady by the semi-chains inclining towards each other, as shown in plan at B; this also causes the suspension rods to incline inward, and, therefore, to have a tendency to return to their original angle. The first bridge constructed on this plan was tested by driving a heavy field gun, drawn by four horses, across the bridge, with the result that no vibration ensued.

It is well known to all who have had practical experience in the ordinary classes of suspension bridges that lateral

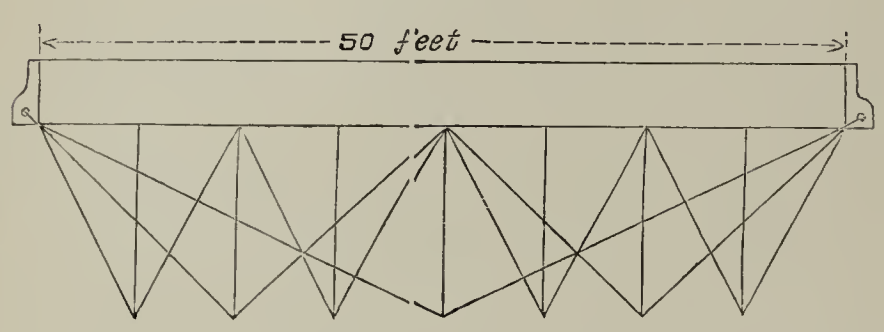
FIG. 23



vibration becomes cumulative. The writer, about 22 years since, experimented upon the Hungerford (London) Suspension Bridge, and found that by merely shifting his weight from one foot to the other in regular time an oscillation of 3 in. occurred at the centre of the main span; the reason of this is clear, as the suspension rods were parallel and of equal lengths, hence, vibration once established, the isochronism of the suspension rods would prevent its diminution. The chains of the Hungerford Bridge have subsequently been used for a bridge on the site for which they were originally designed, that is, at Clifton, near Bristol.

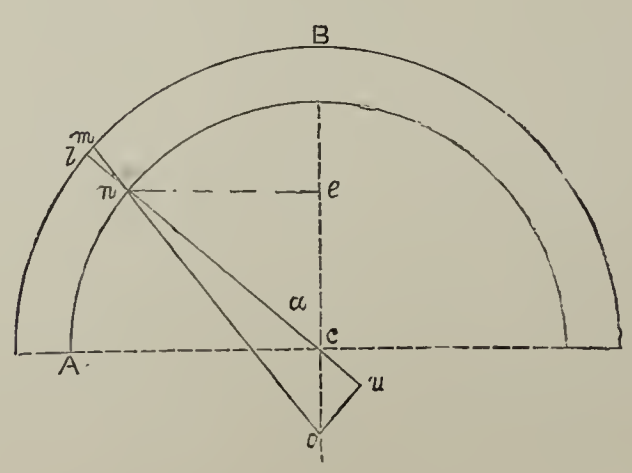
A very good form of trussed bridge was introduced some years back by Mr. Pittar, an elevation of which is shown in Fig. 24. Such a structure should not be used for spans exceeding 50 ft.

FIG. 24



We will now proceed to deal with oblique arches, and the importance of accuracy in designing such structures cannot be over-rated. The late Mr. George Watson Buck was the first engineer who thoroughly entered into the matter, and proved practically how the spiral crosses should be set out, for an

FIG. 25

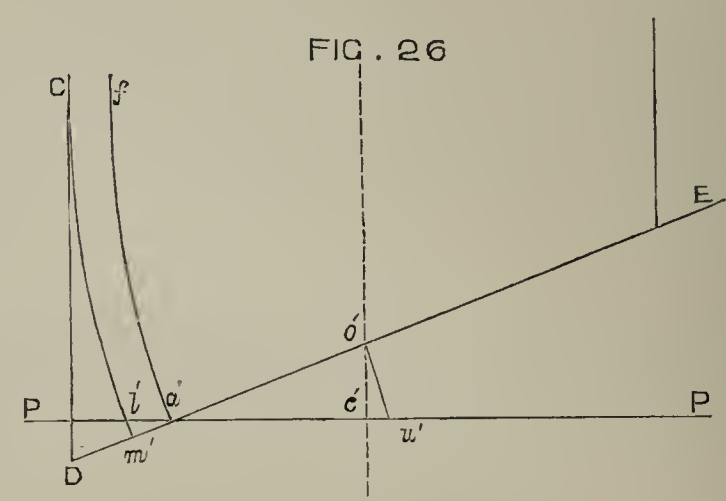


oblique arch, upon the laggings. Subsequently Mr. W. H. Barlow, in a much more concise manner, worked out the whole theory of oblique arches, the demonstration of which we now give, as the paper in which it was originally published is not extant.

Let A B (Fig. 25) be the elevation of a skew arch square to the axis; let c be the centre, and a the point where any face joint, a, m, meets the intrado.

Let C, C, E (Fig. 26), be the plan of the same, a' being the position in plan of a in Fig. 25. Let a vertical plane, P P,

FIG. 26



pass through a, intersecting the spiral surface, $c f a' m'$, in the line a', l'. From l' draw l', m', tangent to the spiral line of the extrado, meeting D, E, in m'. Because P, P, is perpendicular to the axis of the spiral, the line l', a', will be a straight line at right angles to the tangent, l', m'. The triangle, a', l', m', is therefore the projection of a right-angled triangle; in the short distance, l', m', the tangent nearly coincides with the plane of the spiral surface, hence the angle, l', a', m', will closely approximate that formed between the chord of the curved face-joint and the line, l, a, which is the angle required to be found.

In Fig. 25, let la be the projection in elevation of the line, $l'a'$, join ac and produce indefinitely. From o', where the axis intersects D E (face line), draw $o'u'$ parallel to $l'm'$, meeting P P in u', produce ro' to c'. In Fig. 25, on the produced line ac, make la to au as $l'a'$ is to $a'u'$. Through u draw uo at right angles to au, meeting Bc produced in o. Through l draw lm at right angles to la, meeting oa produced in m, from the properties of spiral surfaces, la, au will be in the same straight line, and the (real) triangle aou will be a right-angled triangle, similar to, and in the same plane with, $a'm'l'$, having the angle $o'a'u'$ equal to the angle, $l'a'm'$, also oa is the hypothenuse, and is drawn from the point, a, to the point of convergence of the face joints; $o'u'$ is also the hypothenuse of the triangle, $u'o'c'$ and the (real) angle, $c'o'u'$, equals the angle of extrado.

Let the angle C D E $= \theta$, the angle $c'o'u' = \phi$, the angle $acB = \alpha$, and ac = radius $= r$.

Draw ae at right angles to Bc, then

$ae = r \sin \alpha = a'c', - o'c' = r \sin \alpha \cot \theta, - o'u'$ (real) $= r \sin \alpha \cot \theta \sec. \phi$.

$ou - r \sin \alpha \cot \theta \tan \phi$, $- uc = r \sin \alpha \cot \theta \tan \phi \cot \alpha = r \cos \alpha \cot \theta \tan \phi$.

$$au = r + \left\{ r \cos \alpha \cot \theta \tan \phi \right\}$$

$$\text{Tan } u'a'o' \text{ (real)} = \frac{r' \sin \alpha \cot \theta \sec \phi}{r + \{ r \cos \alpha \cot \theta \tan \phi \}}$$

Let $r \cot \theta \sec \phi = a$ and $r \cot \theta \tan \phi = b$

$$\text{Tan } l'a'm' = \tan u'a'o' = \frac{a \sin \alpha}{b \cos \alpha + r}$$

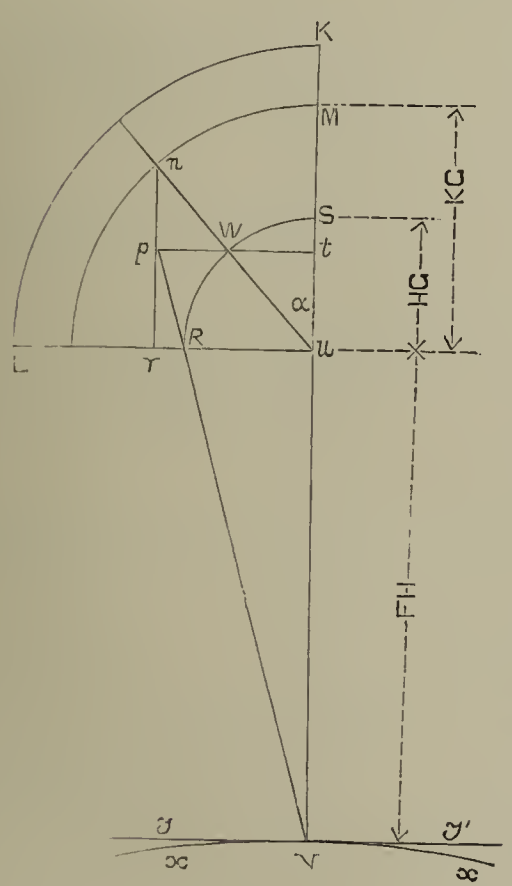
Hence if the arch be semicircular, the angle $l'a'm'$ at springing is:—

$$\tan l'a'm' = \cot \theta \sec \phi \quad \text{co (eccentricity)} = ou \text{ cosec } \alpha$$
$$= r \sin \alpha, \cot \theta, \tan \phi \text{ cosec } \alpha = r \cot \theta \tan \phi$$

The formula $\frac{a \sin \alpha}{b \cos \alpha + r}$ leads to another construction for finding the angles of face and coursing joints.

Let L M (Fig 27) be elevation of half-face of oblique arch on the square, nu being the radius. From K in the straight line K H (Fig. 28) draw K F and K G, making H K F $= \theta$, and H K G $= \phi$. Make K G$=nu$ (radius) and through G draw G F at right angles to K H. Upon vertical line Mu (Fig. 27), produced set-off $n\ V =$ F H and from n with distance H G describe the arc, R Ws. To find the angle for any joint n, join nu, and through W where nu intersects R Ws draw pt parallel to Lu and from n draw nr parallel to Mu intersecting pt in p. Join pV, then pVt is the required angle; for let F H (Fig 28) $= r'$.

FIG. 27



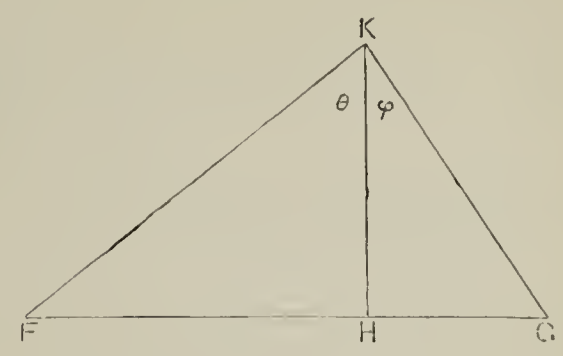
K H $= r' \cot \theta$. K G $= r' \cot \theta \sec \phi$, $-$ H G $= r' \cot \theta \tan \phi$

$tu = r' \cot \theta \tan \phi \cos \alpha$, $-uV = r$

$tV = r' + \{ r' \cot \theta \tan \phi \cos \alpha \}$

$pt = ru = r' \cot \theta \sec \phi \sin \alpha$ (= K G $\sin \alpha$)

FIG. 28



$$\text{Hence } \frac{pt}{tv} = \frac{a \sin \alpha}{b \cos \alpha + r}$$

yy' being drawn at right angles to M V and xx' being the spiral curve applied, so that yy' is a tangent to it at V, $P\ Vx$ and $P\ Vx'$ will give the templates for the joint u on acute and obtuse sides of the arch.

$$\text{Radius of spiral} = \frac{r}{\sin^2 \beta}$$

When β = intradosal angle —

$$\text{H G} = r \times \sin \phi$$
$$\text{F H} = \text{H K} \times \tan \theta$$
$$\text{H K} = r \times \cos \phi$$
$$\text{F H} = r \times \cos \phi \times \tan \theta$$

The late Mr. Buck writes, in the preface to the first edition of his work, that "the period when oblique arches were first introduced is not known; but it has been ascertained that in 1530 an oblique arch was erected at Il Tribolo, near Porta Sangallo, in Florence, on the main road to Bologna. The description of this bridge is given in the writings of Vasari, Volume XI., page 308, the Milan edition, published in 1811."

It is a curious fact that scarcely any oblique arches, elliptical upon the square, have been constructed, although there is no practical objection to the construction of such arches, provided that they are designed by engineers competent to deal with such matters. Probably the most absurd mistakes ever made in the construction of oblique arches were those indicated by an uneducated mason, who directed his readers to make the oblique arches circular segments on the face, instead of circular, upon the square span.

In a future article we purpose showing how an elliptical arch can be set out, and in that article we shall give the lines of the intradosal courses, as it would be necessary to set them out upon the laggings.

(*To be continued*).

THE REGISTRARSHIP OF THE RAILWAY COMMISSION.—Mr. Walter Henry Macnamara, barrister-at-law, of the Oxford Circuit, has been appointed to the office of Registrar to the Railway Commission, vacant by the recent resignation of Mr. J. H. Balfour Browne. Mr. Macnamara, who was called to the Bar at the Inner Temple, in 1874, is a son of the late Mr. H. T. J. Macnamara, one of the original members of the Railway Commission, and he is also the author of the reports of cases decided before the Commissioners. The appointment is at present worth £500 a year; but as the appointment to the office is now conditional upon its holder relinquishing practice at the Bar, it is understood that the emolument attached to it will very shortly be considerably augmented.

(*Continued from page* 43.)

APPENDIX II.—(*continued.*)

1	2	3	4	5	6	7	8	9	10	11	12	13
No. of Pieces.	Makers.	Application.	Year made.	Modulus of Elasticity. Kg. per sq. mm.	Limit of Elasticity. Kg. per sq. cm.	Breaking strength. Kg. per sq. cm.	Contraction of Area per cent.	Elongation in 25 cm. (10 in.) per cent.	Analysis. Carbon per cent.	Sulphur per cent.	Phosph. per cent.	Remarks.
80	S. B. Goldschmitt Mainz	Flats, 45 by 12	1876	—	—	3750	19	9.7				Flat test piece. Fine dull short fibre.
81	ditto	Flats, 60 by 11	1876	—	—	3860	13	8.1				do. Fine short fibre in thin layers. Broke beyond the 25 c.m.
82	ditto	Flats, 60 by 8	1876	—	—	3740	14	11.6				do. Fine fibre.
83a	ditto	Flats, 35 by 5	1876	—	—	2710	17	1.6				do. do. Cracked.
83b	ditto	ditto	1876	—	—	3650	23	10.9				do. do. do.
34a	Gutehoffnungshütte, Sterkrate	Squares for engine work	1876	2 082 000	1880	3810	34			0.04		Fine fibre, in layers, with gaping cracks between layers.
34b	ditto	ditto	1876	2 123 000	1390	3750	36	22.7				Short fibre, with dull streaks, honeycombed, cracked.
71a	W. Hamacher, Barop	Rounds for engine bolts	1877	2 175 000	1620	3600	28	16.8				Short dull fibre, with scattered glittered points; much cracked outside.
71b	ditto	ditto	1877	2 257 000	1670	3600	51	23.9				As last, outside rough, not cracked.
73a	ditto	Squares for carriage work	1877	2 177 000	910	3730	29					Mainly crystalline, with small fibrous patches.
73b	ditto	ditto	1877	2 128 000	1340	3490	11	10.7				Coarse crystal, fine cracks crosswise outside. Flat test piece.
35a	ditto	Flats, 50 by 13	1877	—	—	3625	19	17.2				Fine fibre. Broke beyond the 25 c.m. Flat test piece.
35b	ditto	ditto	1877	—	—	3720	33	24.4				Fine fibre.
84a	Hirsch & Co., Mainz	Rounds for carriage work	1876	—	—	3010	14	5.3				Partly fibrous, partly coarse crystals, fibre dull and dirty, outside much cracked.
84b	ditto	ditto	1876	—	—	2960	10	4.7				As last, crystalline part small, outside much cracked.
33a	Hörder Minc & Forge Co.	ditto	1876	—	—	3750	30	26.2				Fibrous, short and dark, with scattered crystalline spots, outside rough and cracked.
33b	ditto	ditto	1876	—	—	3780	27	20.3				As last.
72a	ditto	Rounds for engine bolts	1877	2 171 000	1850	3650	46	26.3				Fine fibre, scattered glittering points, outside cracked lengthwise.
72b	ditto	ditto	1877	2 142 000	1970	3780	39.5	26.6				As last, but numerous cracks crosswise.
74a	ditto	Squares for carriage work	1877	2 124 000	1660	3730	27					Fine fibre, in layers, with large crystalline spots.
74b	ditto	ditto	1877	2 125 000	1450	3780	20	16.6				Half coarse crystal, half fibrous with crystalline spots, outside cracked.
124a	ditto	Engine parts	1876	—	—	3800	54	27.8				Fine fibre, somewhat cracked outside.
124b	ditto	ditto	1876	—	—	3650	33	23.6				As last, with glittering points.
135a	ditto	ditto	1877	2 219 000	2040	4180	42					Fine fibre, dark and light grey, with crystalline spots, outside cracked.
135b	ditto	ditto	1877	2 169 000	2220	3890	48	21.0				Fine fibre, in layers, with gaping cracks, fine cracks lengthwise outside.
86a	Hüttenberg Iron Works	Engine bolts	1876	2 257 000	1530	3210	48					Fine fibre, bright grey, with dark honeycombed layer through middle; outside cracked.
86b	ditto	ditto	1876	2 265 000	1230	3290	45	24.6				Short fine fibre, dark, irregular, with one crystalline spot; outside cracks lengthwise.
62a	Innerberg Works	Sundry purposes	1877	—	—	3160	26	13.4				Fine fibre, dark, irregular, in layers, fracture very oblique.

1	2	3	4	5	6	7	8	9	10	11	12	13
No. of Piece.	Makers.	Application.	Year made.	Modulus of Elasticity. Kg. per sq. mm.	Limit of Elasticity. Kg. per sq. cm.	Breaking strength. Kg. per sq. cm.	Contraction of Area per cent.	Elongation in 25 cm. (10 in.) per cent.	Analysis. Carbon per cent.	Sulphur per cent.	Phosph. per cent.	Remarks.
62b	Innerberger Wks.	Various uses	1877	—	—	3160	39	26.2				As last, with cracks ; cracks lengthwise and crosswise outside.
85a	ditto	Engine bolts and nuts	1876	2 187 000	930	3050	38					Fine fibre, one-third very dark grey, rest quite white, with sulphur-yellow tinge.
85b	ditto	ditto	1876	2 188 000	920	3030	54	27.7				Fine fibre in layers ; much cracked outside.
61a	ditto	Squares, various uses	1875	—	—	3210	39	25.5				Short fibre in layers, with strong yellow tinge in places ; cracks.
61b	ditto	ditto	1875	—	—	3110	27	14.5				As last.
59a	ditto	Flats, 50by17	1875	2 042 000	1540	3110	45			0.04	0.027	Flat test piece. Broke obliquely, very fine fibre. A little arsenic.
59b	ditto	ditto	1875	2 171 000	1280	3060	54	28.0				Ditto. Very fine fibre, but short.
60a	ditto	ditto, 52by26	1876	—	—	3430	46	25.1				Ditto. Fine clear fibre, in layers.
60b	ditto	ditto	1876	—	—	3430	52	26.4				Ditto ditto
129a	ditto	ditto, 52by13	1876	—	—	3530	41	24.2				Ditto. Fine fibre, in thin flattened layers.
129b	ditto	ditto	1876	—	—	3520	37	24.9				Ditto ditto
63a	St. Egidi-Kindberg, Steiermark	Rounds, various uses	—	—	—	3240	36	22.7				Partly fibrous and grey, partly dirty, crystalline, and bright.
63b	ditto	ditto	—	—	—	3240	27	14.8				As last, cracked outside.
64a	ditto	Squares, various uses	1877	2 227 000	1220	3570	21					Fine fibre, clear and dark grey, irregular transverse cracks.
64b	ditto	ditto	1877	2 285 000	1310	3490	27.8	18.8				Short dark fibre, irregularly mixed and cracked ; cracked outside near fracture.
24a	Königs & Laurahütte	Rounds, for engine work, 46 mm.	1876	2 197 000	1530	3770	44.5					Cracked and bad ; could not be used without re-heating. Fibrous fracture, with some small crystalline spots.
24b	ditto	ditto	1876	2 195 000	1230	3800	49	24.3		0.01	0.119	Ditto. Fibrous, light and dark grey, with scattered crystalline spots.
25a	ditto	Squares, for ditto, 39mm.	1876	2 226 000	1530	3920	40			0.00		Ditto. Fibrous, irregular, light and dark grey, mixed with a few small crystalline spots.
25b	ditto	ditto	1876	2 092 000	1850	3950	35	24.7				Ditto. As last.
26a	ditto	Flats, for ditto, 65by12½	1876	2 104 000	1120	3690	28	16 8				Flat test piece. Fine layers, dark and light, with distinct coloured streaks ; some crystalline spots.
26b	ditto	ditto	1876	2 062 000	1110	3570	26	14.0				Ditto. Fracture as last.
49a	ditto	Rounds, for carriage work	1876	2 116 000	1310	4140	28	20.6				Good in working. Partly fibrous, light and dark grey mixed, with some crystals; partly quite crystalline.
49b	ditto	ditto	1876	2 136 000	1310	4040	14	12.2				Ditto. Coarse crystal on one side, merging towards the other into fine grain.
50a	ditto	Flats, for carriage work 58 by 26	1876	1 933 000	1030	3660	29.5	25.0				Flat test piece. Good in working. Very fine fibre. Broke at deeply stamped letter.
50b	ditto	ditto	1876	1 983 000	1030	3630	29.5	24.2				Ditto ditto. Very fine fibre.
156a	ditto	Rounds, for smiths	1877	—	—	3880	35	20.0				Fibre in layers, with brighter grain and some cinder in patches.
156b	ditto	ditto	1877	—	—	3950	34	20.4				As last.
157a	ditto	Squares, for smiths	1877	—	—	3890	39	26.6				Dull fibre, light and dark mixed irregularly, with bright spots of grain. Cracks lengthwise outside.

1	2	3	4	5	6	7	8	9	10	11	12	13
No. of Piece.	Makers.	Application.	Year made.	Modulus of Elasticity. Kg. per sq. mm.	Limit of Elasticity. Kg. per sq. cm.	Breaking strength Kg. per sq. cm.	Contraction of Area per cent.	Elongation in 25 cm. (10 in.) per cent.	Analysis. Carbon per cent.	Sulphur per cent.	Phosph- per cent.	Remarks.
157b	Konigs-und Laurahütte	Smiths' squares	1877	—	—	3950	42	26.6				As last, but no cracks.
38a	Kramer Bros., St. Ingbert	Coupling-hangers, 49 by 14	1877	—	—	4000	24	12.0		0.12	0.358	Flat piece. Fine fibre, short and dull.
38b	ditto	ditto	1877	—	—	4070	26	15.2				Ditto. As last.
36a	ditto	Coupling-straps	1877	2 053 000	1220	3615	17					Fine dark grey fibre, with spots of coarse crystal.
36b	ditto	ditto	1877	2 069 000	1300	3710	20	11.6				Short fibre, dirty, with crystalline spots, slightly cracked outside.
37a	ditto	Coupling-nuts	1877	—	—	3570	16	14.6				Coarse crystal ; outside rough, but not cracked.
37b	ditto	ditto	1877	—	—	3410	23	13.1				Short fibre, dull black, with scattered crystalline points, much cracked outside.
16a	Prinz Leopold Co., Empel	Coupling-pins & shafts	1877	2 041 000	1310	3430	29.5			0.005		Fine fibre, with some glittering grains.
16b	ditto	ditto	1877	2 189 000	1380	3510	32	20.8				Short fibre, honeycomb and crystalline spots, with yellowish tinge ; outside much cracked.
14a	ditto	Flats, 60 by 15	1876	2 068 000	2550	3930	19					Flat piece. Fine layers, with gaping unwelded cracks.
14b	ditto	ditto	1876	1 986 000	1850	3700	22			0.00		Ditto. As above.
15a	ditto	Flats, 47 by 8	1876	2 116 000	1710	4030	44					Ditto. Very fine uniform grain.
15b	ditto	ditto	1876	2 054 000	1220	3950	39	19.7				Ditto. As last.
3a	ditto	—	—	2 122 000	1620	3700	63		0.14	0.00	0.0866	From mixture of 3 brands of pig ; very fine fibre, grey.
3b	ditto	—	—	2 163 000	1630	3720	63					Ditto. As last.
4	ditto	—	—	2 100 000	1500	3700	62		0.13			From a single brand. As last.
52a	Konigin Maria-hütte	Smiths' work	1876	2 146 000	1270	3820	32			0.07	0.340	Moderately good iron. Crystalline one side, fibrous the other, lengthwise cracks outside.
52b	ditto	ditto	1876	1 967 000	1500	3190	28	15.5				Square piece. Moderate iron. Dark coarse fibre, with honeycomb ; much cracked outside.
53	ditto	Smiths' flats, 75 by 10	1877	2 031 000	1710	3770	20	12.9				Flat piece. Moderate iron. Dark short fibre in fine layers, with some crystalline spots.
158a	Marthahütte, Kattowitz	ditto, 58 by 10	1877	1 978 000	1490	3920	27					Ditto. Fine dark fibre in layers ; one crack lengthwise outside.
158b	ditto	ditto	1877	2 041 000	1560	3740	26	15.1				Ditto. Fine fibre, short and dull ; one deep crack lengthwise outside.
143a	Neuberg-Mariazell Co.	Engine-parts	1876	—	—	2950 ?	53	29.3				Fine fibre, in bright layers ; somewhat cracked,
143b	ditto	ditto	1876	—	—	3670	42	30.0				As last,
141a	ditto	Lattice-iron for engines	1876	2 267 000	1120	3060	33					Fracture not instantaneous, but gradual tearing from one side. At this side a large yellowish-white patch, crystalline ; rest fibrous, with much honeycomb. Crosswise cracks near the fracture.
141b	ditto	ditto	1876	2 200 000	1220	3260	45	22.2				Clear dark fibre, irregular, with gaping cracks. Much cracked outside.

1	2	3	4	5	6	7	8	9	10	11	12	13
No. of Piece.	Makers.	Application.	Year made.	Modulus of Elasticity. Kg. per sq. mm.	Limit of Elasticity. Kg. per sq. cm.	Breaking strength. Kg. per sq. cm.	Contraction of Area per cent.	Elongation in 25 cm. (10 in.) per cent.	Analysis. Carbon per cent.	Sulphur per cent.	Phosph. per cent.	Remarks.
139a	Neuberg-Mairazell Co.	Engine flats 51 by 17	1876	1 886 000	960	3330	54	—				Flat piece. Fine bright grey fibre, honeycomb in centre.
139b	ditto	ditto	1876	2 047 000	1130	3360	54	30.2				Ditto, very fine fibre, crack in centre.
111a	Quint, Trier.	Rounds for heavy smith work.	1876	2 081 000	820	2160	9	—		0.06 to 0.03	0.378 to 0.329	Partly dark grey fibre, partly bright and dirty ; black patch of cinder, and honeycomb ; much cracked outside. Coarse brittle iron.
111b	ditto	ditto	1876	2 054 000	880	2480	6	—				Dirty appearance, bright and dark mixed irregularly ; cracks outside.
112a	ditto	ditto	1876	2 164 000	1290	3520	9.5	8.9				Coarse crystals, in layers.
112b	ditto	ditto	1876	2 060 000	930	3160	7	6.8				Short dark fibre, with spots of coarse crystal ; much cracked outside.
115a	ditto	ditto	1876	2 081 000	1970	3830	47	27.4				Fine dark uniform fibre ; outside rough, but not cracked.
115b	ditto	ditto	1876	2 115 000	2020	3830	46	26.3				Ditto, as last.
116a	ditto	Squares for brake-shafts, &c.	1876	—	—	3710	34	21.7				Fibrous, with small spots of crystal, and a deep crack ; outside very slightly cracked.
116b	ditto	ditto	1876	—	—	3260	15	9.5				Dull fibre, with square patch of cinder or burnt iron ; outside a deep gaping crack lengthwise. Brittle coarse iron throughout this series.
89a	ditto	Flats for hvy smith work, &c. 39 by 20	1876	1 837 000	1080	3630	28	17.3				Flat piece. Short fibre, honeycomb, and irregular cracks.
89b	ditto	ditto	1876	1 889 000	1010	3540	27	11.4				Ditto, as last.
90a	ditto	ditto 37 by 24	1876	2 073 000	1580	3960	18	17.6				Ditto, half fine fibre, half crystal, in thick layers.
90b	ditto	ditto	1876	2 191 000	1220	3910	23	17.6				Ditto, fibrous throughout, with scattered crystalline points.
92a	ditto	ditto 50 by 19	1876	1 986 000	1060	3620	18	11.3				Ditto, as last.
92b	ditto	ditto	1876	1 998 000	1070	3680	19	10.7				Ditto ditto.
93a	ditto	ditto 50 by 15	1876	2 031 000	1200	3250	12	8.2				Ditto, fine layers, but short and dull ; dirty and burnt in middle.
93b	ditto	ditto	1876	2 046 000	1110	3740	17	12.6				Ditto, fine layers, without defects above.
94a	ditto	ditto 48 by 14	1876	1 847 000	1110	4000	14	—		0.20	0.433	Ditto, fine fibre, with flaw about 4 square mm., and a bad weld right through.
94b	ditto	ditto	1876	2 093 000	1380	3900	19	15.8				Ditto, fibrous, with many crystalline spots.
95a	ditto	ditto 50 by 23	1876	1 806 000	1100	3780	25	19.8				Ditto, fibrous throughout.
95b	ditto	ditto	1876	1 810 000	1370	3800	23	16.4				Ditto, half fine fibre, half crystal.
96a	ditto	ditto 54 by 20	1876	1 775 000	914	3710	18	12.1				Ditto, short fibre, with some crystalline spots.
96b	ditto	ditto	1876	2 008 000	911	3710	18	13.1				Ditto, as last.
99a	ditto	ditto 79 by 14	1876	1 962 000	1450	3660	—	9.9				Ditto, broke at beginning of neck ; fine layers, with some crystalline spots.
99b	ditto	ditto	1876	1 964 000	1640	3660	18.5	9.1				Ditto, fine layers, with small crystalline spots.
106a	ditto	ditto 105 by 20	1876	2 013 000	1020	3660	11	8.3				Ditto, half short fibre, half coarse crystal.
106b	ditto	ditto 105 by 22	1876	1 991 000	900	3630	18.5	13.5				Ditto, fibrous throughout, with small scattered crystals.
c	ditto	ditto 105 by 22	1876	2 013 000	1510	3515	16	9.3				Ditto, as last.

(*To be continued.*)

RAILWAY SIGNALLING.

CONCLUSION ON POINT LOCKS.

(*Continued from page* 35.)

IN concluding this important portion of our subject, it will be now appreciated that it has only been by years of patient perseverance, and the result of practical and observant experience, that the present comparative degree of perfection and efficiency in this branch of railway engineering has been achieved. And the importance and room for study in such department can scarcely be over estimated, when we consider that upwards of two-thirds of the railway collisions and accidents requiring the investigation of the Board of Trade, are attributable to some failure or improper working of facing points.

Little has been said with regard to "trailing points" (which should always be arranged where practicable), but it will be obviously understood, that they are worked in an exactly similar manner to "facing points," but do not require to be locked; facing points serving for conducting traffic in a "convergent," and the latter in a "divergent" relation to the main line, with which they are connected. We have previonsly pointed out that there are certain facilities achieved in working traffic by the use of the former.

Some few years ago considerable difference of feeling and opinion existed as to the comparative advantages and ultimate efficiency of mechanical appliances over well-trained and intelligent men, and many disasters were then termed by railway authorities, (opposed to the adoption of the former), "Board of Trade Accidents," as these latter gentlemen were advocating the extension of mechanical devices in all cases where possible. Of course there are some sound premises of argument (even at the present time) both for and against either side, but we think there can be few now of knowledge and experience on this subject, however prejudiced, who can entirely ignore the multifarious and manifold advantages, both in regard to safety and efficiency of working railway traffic achieved by the development of mechanical ingenuity.

Not many years ago, one of our most eminent and practical railway chairmen openly expressed his aversion to the extension of mechanical science to railway working and control, for although he admitted the ingenuity and ability displayed in this direction, still he had more confidence in the "appliances provided by a Higher power," viz.—mankind. In regard to such opinions, we venture to think that it would be difficult to find a more appropriate reply than that propounded by Sir Henry Tyler in one of his able papers, viz.: "Under no system known can perfect safety be obtained . . . . but confidence in a Higher power . . . . can only with propriety be entertained after all reasonable means have been exhausted."

Of late years, the addition of "safety points" in cases of good lines and sidings, have been considerably extended, whereby the control of signalmen is greatly enhanced. But although at the present time there are upwards of 16,800 places in the United Kingdom provided with such appliances, still there remains about one-fourth of the above number yet to be similarly protected.

The careful inspection and maintenance of all points and their connections cannot be over-estimated as ensuring both safety and efficiency of traffic.

These duties are usually placed under the strict charge of competent signal and point inspectors, residing in some handy and convenient locality, and under whose supervision a suitable amount of ordinary labour is placed, and who have certain sections to visit daily. Men are appointed to perform special inspections, repairs, cleanings, &c., and to report, by a formal written statement, the condition of affairs to their inspector. But in some cases the signalmen are held responsible for the condition and order of their apparatus, and at all times are required to try their points and signals, to ascertain the capabilities for performing their proper functions when required. This precaution is especially necessary during variations of temperature, and would be especially desirable at nights after hot days in the summer, and similar measures must be observed in the winter, particularly during frost or snow.

Signalmen are also required to observe that their actuating wires and connections are properly adjusted by means of the regulating screws or couplings, but any breakdown or adjustment of the points are usually attended to by "gangers" until the "chargeman" of the district or section is communicated with and can attend; and while any such defects are being remedied or repaired, a signal or notice board is temporially erected to warn drivers and other servants connected with this department the state of affairs. The signalman on duty at the time, at the particular place where any defect occurs, is usually requested to sign the "repairers'" report sheet, and the time occupied by such repairs. Of course, our various railway companys provide there own special code of rules and arrangments for the inspection and maintenance of this department, but the above remarks will be found to form about the general basis common to all of them, and which may be extended and subdivded according to fancy and advisability. Finally it may be useful and in place to here annex all the memo-

randa of important requirements of the Board of Trade, which relate to the arrangement and operation of railway points or switches, and which are as follows :—

MEMORANDA.

"The levers of points and signals should be brought close together into the position most convenient for the person working them, and should be interlocked. The points should be provided with double connecting rods. The levers of the points should be sufficiently long to enable the pointsman to work them without risk or inconvenience, and should not be placed on the ground between the lines of rails.

"The facing points should be provided with an apparatus which will ensure the points being in their proper positions before the signals are lowered; and which will prevent the signalman from shifting the points whilst a train is passing them.

"Facing points should be avoided as far as possible, but when used, they should be secured by facing-point locks and locking bars; the length of the locking bars should exceed the greatest distance between the adjacent wheels of passengers' carriages, and the stock rails should have the gauge preserved by gauge-ties. When facing points cannot be dispensed with, they should be placed as near as possible to the levers by which they are worked or bolted, and in no instance at a greater distance than 150 yards from those levers. The points should be worked or bolted by rods and not by wires.

"The sidings should be so arranged that the shunting carried on at them shall present the least possible obstruction to the passenger lines. There should be safety points upon each goods and mineral line and siding, with the points closed against the passenger lines and interlocked with the signals. In the case of sidings joining single lines on favourable gradients, where the train staff and ticket system is in use for working the traffic, a key attached to the staff may be used for opening the sidings, and signals may be dispensed with.

"No siding should join a passenger line on a steeper gradient than 1 in 260, except where it is unavoidable. When the line is double, and the gradient at a station or siding junction is necessarily steeper, and when danger is to be apprehended from vehicles running back, a catch siding, with points weighted for the sidings should be provided further down the incline than the passenger platform, siding junction, or goods yard, to intercept runaway vehicles. Under similar circumstances, when the line is single, in the case, 1st of a station, a second line should be laid down, a second platform also constructed, and a catch siding similarly provided; and in the case, 2nd, of a siding junction, means should be provided for placing the whole trains in sidings, clear of the main line, before any shunting operations are commenced."

INTRODUCTION TO INTERLOCKING RAILWAY POINTS AND SIGNALS.

In our general introduction to "Railway Signalling," we mentioned that in about the year 1846, it became customary to concentrate, within cabins or boxes, as many signal and point-levers as could be reliably operated by one man. But such concentration of levers, although effecting considerable advantages, was necessarily the means of developing another dangerous liability, namely, that of the signalman in charge becoming confused with the number of levers before him, and so temporally forgetting to what they related, or certain conditions resulting or existing from certain movements, whereby there was a great risk of pulling or operating a wrong lever, and thus giving an incorrect or conflicting signal.

As our railway systems began to be rapidly extended and developed—meaning greater complication of junctions and distribution of traffic—it soon became apparent that some reliable system would have to be devised to secure an harmonious working between the points and signals, so as to prevent any indiscriminate operation of the levers, which might cause signals to be given at variance to the road prepared for an approaching train.

In order to now thoroughly understand and appreciate the uses and development of the so-termed "interlocking system," we will commence by briefly tracing its career from its earliest stage, and then pass on until we are in a position to consider the beautiful and comparatively perfect arrangements of apparatus of the present day, and for this purpose we cannot do better than commence by observing and analysing the conditions and requirements of traffic at an ordinary junction of a double main and branch lines, and for this purpose we shall refer to Fig. 190, Plate CXLIII.

Upon examining the diagram, it will be at once evident that whenever a train is required to pass from one line to another (as would be the case from the main to branch or *vice versa*), it must be properly protected from the liability of colliding with any other train or trains. For, assuming the signals to be so independently arranged of each other's action, that by some carelessness or blunder both signals should be taken "off" or lowered at the same time, for the "up branch" and the "down main," lines, then there would be a very great risk that one train would cut the other in two by crossing each other's path of traffic. Also, if the signals should allow two trains to approach the junction at the same time, on both the "down main and down branch lines," there would be a great risk of one train running into the other. But, on the other hand, it would be perfectly safe for a train to pass along the "main up line," and another at the same time traverse the "down branch line."

"Thus at an ordinary junction, governed by four (stop or

home) signals, it would be possible to give sixteen different visible indications, two of which would be unintelligible or without meaning, and six positively dangerous.

And not only must they be so arranged and controlled as to be incapable of giving palpable conflicting signals, but all the working of the points must be rendered so mutually dependent, that when a signal is given only the right and relative road is prepared for the approaching train.

In addition to the four "stop or home" signals, provided at the junction, there would be four corresponding "distant signals," as shown, worked by wires from the junction box. And further, there would be two point actuating levers, independent of the usual corresponding supplementary locking levers. But only taking into consideration "the home signal and point actuating levers," there would be sixty-four possible combinations, out of which only thirteen would be safe. It will be, therefore, readily appreciated what an enormous number of conflicting combinations would be at present possible, in some of our large signal boxes, provided with fifty to one hundred levers, had not some means been devised to limit or control their operation within the precincts of harmony and safety.

In the Cannon Street station box there are upwards of seventy levers for working the points and signals, the possible combination of which could only be roughly estimated at some millions, but by the so-termed "inter-locking system" (hereinafter explained), only about 800 safe combinations are allowed.

Some little difference of opinion exists amongst many versed in this department of railway matters, as to how, and when, this valuable system originated; and it may be perhaps a little difficult, owing to fine technical definitions and distinctions about the word "inter-locking," and its real meaning, to state the exact commencement, and a chronological relation of fact which will meet with every one's approval.

But, putting aside any individual interest or fancies, it will be fairest and most satisfactory to give credit to many, and all those able and ingenious gentlemen, who, from time to time, have kept on incessantly building upon one anothers work step by step, until it has ultimately resulted in an invaluable and comparative perfect "system," to which the safety of our railway traffic is at present mainly dependent.

Probably the first important step towards adopting some elementary method and contrivance for obtaining some degree of such concurrent action between railway signals was that introduced by Mr. C. Gregory, in about 1843, who, about this date, was the Resident Engineer of the Croydon Railway. At this time very few mechanical inventions were known to the railway world, and indeed, some considerable feeling existed against their speedy adoption, as many leading authorities strongly believed that careful and intelligent men were the greatest safeguards.

The Liverpool and Manchester Railway was then generally considered to be the example of discipline and arrangement, although they possessed no uniform tabulated rules or instructions.

Mr. Gregory availed himself of an early opportunity of visiting most of the English railways of importance then opened, displaying that careful observation, with a view to railway improvement and development, that we have had occasion to previously notice.

At Fig. 191 (Plate CXLIII.) we illustrate this gentleman's early apparatus before alluded to, and as applied at the Bricklayer's Arms Junction, for preventing the actuation of conflicting signals. For this purpose, the chains or connections of the signals were concentrated in and suitably attached to parts of a so-termed "stirrup frame," consisting of rods or bars, *a*, *b*, *c*, *d*, having stirrup pieces, *e*, capable of reciprocating vertically in the framing, as represented.

Link motions, *f*, were attached to the intermediate frames, consisting of limbs, working somewhat similar to a parallel motion, only the one limb of each set being rather longer than the other, necessitated the one standing out in an an oblique or angular direction, when the other was caused to occupy a vertical position. In this manner it will be readily seen that when one stirrup-piece, *e*, on the signal rods was capable of being pulled down, the links on either side thereof must be free to occupy a vertical and parallel plane, and by assuming such position, would force out their other limbs into the angular position, before referred to, so as to prevent the other stirrup-pieces and rods on either side of it from being also pulled down at the same time. Thus, assuming the rods, *a*, *b*, *c*, *d*, to be connected with the up main, up branch, down main, and down branch signals respectively, any conflicting operation of the same would be prevented.

At this time the point-levers were not arranged in conjunction with such apparatus, but, were worked by independent hand-levers in the immediate vicinity, the signals being actuated by the operator placing one foot in the required stirrup-piece.

Subsequently some primitive connection between the point-levers was adopted in a similar manner, although for various reasons, the results were far from efficient.

However, this contrivance of Mr. Gregory's, although comparatively rough, is worthy of every recognition as it was the starting point of a series of most valuable inventions, although, perhaps, as there was no actual mechanical control existing between the points and the signals, it may not be critically considered to be within the exact definition of "interlocking." In 1847 Mr. Stevens devised a method for preventing the actuation of conflicting signals in an exactly similar manner to that first mentioned, but there was also no mechanical connection provided between the point levers and signal stirrups.

Probably, the first instance of some primitive piece of apparatus being arranged for effecting a kind of mutual control over the movements of a pair of points and its signals, was that provided by Mr. Atkinson, in 1852, at East Retford Junction.

It was an extremely simple appliance, as will be understood by reference to Fig. 192, and only capable of very limited application; although, fairly, it certainly must be considered to substantially exhibit the germ of early interlocking. The principle of action is exactly similar to those analogous devices explained with reference to point-locking given in some of our recent numbers. That is *h* is a perforated rod or bar connected to the tongue points, and working in suitable guides in concert with the same, at right angle to the rod; *g* is a rod connected to and working in a vertical plane with the relative semaphore, or its gear. The signal-post carrying such gear was erected in close proximity to the points, so that the perforated bar or rod *h*, connected with the latter, should move in a transverse direction immediately beneath the aforesaid semaphore-rod *g*. Now, unless the points were standing right for the "main line," it was rendered mechanically impossible to lower the "main signal," for to effect such movement the rod *g* had to pass through the perforation, or hole, provided in the transverse point bar *h*, and which could only be the case when the points had been properly set as might be pre-determined.

When the allowed signal had been lowered, or given, the position of the points was incapable of being altered, as the rod passing through the aperture in the switch-bar prevented any subsequent movement thereof, until the signal had been returned to its "danger" attitude. When the points were standing for the "branch line" the "main line" signal was rendered inoperative by the solid part of the bar or rod, *h*, having been moved beneath the semaphore rod, *g*, so as to interrupt any movement of the same.

In this manner, conflicting signals were prevented from being given to trains running from Gainsborough to Manchester, but it did not then pretend to control in anyway the signals of the branch line, which was, of course, very necessary.

Nevertheless, it was a meritorious scheme, for it had awakened necessities serving in some measure or degree, as a link for the future. Mr. Atkinson had set himself a mechanical problem; and although his solution was—I think we may judiciously state—necessarily primitive, yet it surely must be allowed that he succeeded in devising an "element" which was, and is, indispensible in any interlocking frame.

The way it was achieved may be now deemed obviously simple, as rough (most inventions are in their infancy), but it certainly resulted in an elementary interlocking action between a set of points and its signal, although it did not assay to interlock any other points or signals concerned in the system. It has been termed by some interested and versed in these matters, a "point indicator," but that might also be applied to any corresponding elements or parts in the present interlocking frames, which also indicate by some mechanical impediment or obstruction that certain points are occupying a definite and appreciable position. Therefore, such term is misdirecting and unjust, as it would lead us to suppose, by common interpretation, that the only control or check over the signals was by some independent visible indication as to the condition or position of the points, and that no mechanical obstruction existed to prevent any careless or inadvertent mistakes.

Similar primitive controlling devices to that last-mentioned were afterwards much used, and one of which is shown at Fig. 193. Very little description will now be necessary with regard to such contrivances, as similar pieces of apparatus have been fully explained in our treatise on "Point Locks."

J, is a goose-neck bar, having the parallel projecting piece, *i*, and connected at both ends with the chain, *l*, which communicates motion for actuating the signal. At right angles is situated the switch or point bar, *k*, having a suitable aperture formed therein to receive the projection, *i*. In the drawing, the points are shown as free to be moved, and when this has been properly effected, the relative signal may be lowered, whereby the piece, *i*, is drawn through the aperture provided in the switch bar, *k*.

In this manner a mutual control is obtained between the points and its signals in exactly the same way as before described.

It will be also obvious that in lieu of a perforated switch bar, transverse notches might be provided in both the said bar and goose neck, so that the latter would first have to be moved a certain distance before the switch bar would correspond with the notch, through which it must effect its movement.

We will now pass to about three years later (*i.e.*, 1856), when Mr. John Saxby, of the London and Brighton Railway Company, introduced his important and original invention, whereby, for the first time in the annals of railway engineering, a mutual and concurrent mechanical control was achieved between all the points and signals of a railway junction, so as to secure, not only the harmonious working of those points and signals in direct relation thereto, but all the other signals in connection with the system.

This meritorious invention of Mr. Saxby's, in 1856, is now generally admitted to be the true and recognisable fundamental or starting point of the "interlocking system," as now understood. This able and ingenious gentleman has certainly been to this department of railway engineering, what Stephenson was to the locomotive, and further, we are not only enabled to congratulate so useful and worthy an inventor as being the parent of this original device of 1856, but to be able to recognize and

appreciate his continual improvements from that date to almost the present day, having been the sole or joint inventor or proprietor of about one hundred valuable Patent Rights.

The first important apparatus of this type was erected at Bricklayers' Arms Junction, and arranged so as to safely control the operations of eight semaphore and six point levers, so that it was impossible to give any signals conflicting to each other, or contrary to the position of the road.

The following are some of the interesting circumstances connected with the original history, introduction, and development of this early invention.

"Bricklayers' Arms Junction (about 2½ miles from London Bridge), was a point where all the London and Brighton, London and Croydon, London and South-Eastern trains, leaving London had to pass; all trains coming from London travelling on the one and same line. At this Junction the London and Croydon trains were turned on to an extra line provided for these trains only, so that they arrived at New Cross Station at one platform, and the Brighton and South-Eastern trains at another.

On one particular occasion a signalman at Bricklayers' Arms Junction lowered the signal for a Brighton train to pass, but neglected to open the relative points, so that the train was turned on to the Croydon line, causing it to travel under the arch on the left hand side, instead of on the right, so that had it happened that a train had been standing on this part of the Croydon line, a sad accident must have resulted. This fortunate escape did not pass unheeded by Mr. Saxby, who immediately commenced to think over, and devise some scheme to prevent its re-occurrence. At this time the points were worked by levers, and the signals by treadles, as before described. After much consideration it occurred to him to dispense with the treadles, and work both points and signals with levers, and which arrangement was incorporated in his "Specification to Letters Patent, of 1856," and which will be more fully described latter on.

"Keymer Junction, on the London and Brighton Railway, was really the first place were an interlocking apparatus was fixed, which was in the same year. It consisted of two point and four semaphore signal-levers, which were suitably interlocked. The three distant-signals being worked by wheels, and not so controlled. In the year 1858 the "distant-signals," at Uckfield Junction, were interlocked for the first time, in which instance the two point, four semaphore, and distant-signal levers, were all suitably interlocked, and which arrangement was subsequently patented by Mr. Saxby. The apparatus at Athlone (Ireland), Worcester Junction, Battersea Junction, and a few others, were really all the interlocking frames which existed up the year 1860.

"Ultimately, the Brighton Railway Company purchased Mr. Saxby's patent of 1856. In 1860, when the Victoria Station had to be "signalled," Mr. Saxby had occasion to interview the Manager, Engineer, and other officials of the railway, in order to subsequently confer with Colonel Yolland (the Government Inspector), Mr. Fowler (the Engineer), Mr. Kith (the Contractor), and other officials of the Company. The line from Battersea to Victoria being at that time an independent Company from the Brighton Railway.

Mr. Saxby was afterwards really appointed to arrange the signals for the Brighton Company, but as these above-mentioned gentlemen could not agree as to the arrangement and position of the signals. Mr. Fowler, the engineer, said he would do the signalling himself, whereupon the Brighton Railway Company recommended Mr. Saxby to offically carry out the work for Mr. Fowler. And, it was in scheming out these arrangements, that Mr. Saxby found his apparatus of 1856, would be very complicated, the signals having to be fixed to the iron principals of the roof, and therefore, to simplify the matter, he devised the locking-frame, which was patented by him in July 1860 (and which will be described in our next number). Very soon after this work had been completed, Mr. Saxby was asked by Mr. Sinclair, of the Great Eastern Railway, to interlock the points and signals of Stratford Junction, where there were twenty-two levers; and, upon its completion, a meeting of railway officials was held, to inspect and report upon the result. Soon after Mr. Saxby was asked to attend a board meeting of the Directors and officials of the London and North-Western Railway at Birmingham, in order to show them a model which he had most ingeniously arranged in a box, to demonstrate the efficiency of his interlocking system. And it was so contrived that when the box was opened, the lid and sides exhibited a plan of a junction with signals and appendages to suit the levers. Mr. Saxby having opened his mysterious box and laid it before the gentlemen present, retired from the board-room; whereupon shortly afterwards most of the gentlemen tried to again close the box left for their inspection, but to their utter astonishment found their attempts but futile, and there seemed little prospect of success, short of permanently injuring or breaking the model. When Mr. Saxby returned to the room, he showed them how by the proper order or sequential movement of the parts, the box might be closed.

The Directors then agreed to give the "Interlocking System" an introduction, and, with this object, they consulted each other in order to determine the worst or most difficult place they had, so that they could give Mr. Saxby a thorough trial. The position agreed upon was the New Street Station, Birmingham, and Mr. Saxby was asked to tender a plan and price to carry out the work. Subsequently, it was found that the working of the whole traffic at this part could be controlled by two men, whereas it had been believed to be impossible to work the station safely with less than ten or twelve.

In 1862 the Metropolitan Railway and other works

came on, and this method became rapidly and more extensively adopted; and in the year 1863, Mr. Saxby took a partner, Mr. Stinson Farmer (also formerly of the Brighton Railway Company), who have since jointly carried out work in every part of the world in which railway enterprise has flourished.

We must now turn back to briefly glance at the actual construction and arrangement of Mr. Saxby's interesting and original locking frame of 1856, and for this purpose we must refer our readers to the part front and side elevation, illustrated jointly at Fig. 194 of the drawings.

A, is the lever by which the signals and points for the "up line" are actuated, and similarly, by A^1, for those of the "down line."

B, is lever, by which the signals of the "up line" may be operated when the points do not require alteration, and, B^1, is a corresponding lever by which the signals of the "down line" may be similarly moved without interfering with the position of the points.

The levers, A A^1, extend below the framing, and terminate with cranks, a a^1, mounted on fulcra at b, about which they work.

The cranked ends are suitably connected to the points, to be actuated by the connections, c c^1. All the levers work in conveniently formed quadrant guide frames having notches suitable provided for the reception of spring catch rods.

The lower ends of the semaphore rods terminate with slotted links, d, and a, while so termed, triple and double crank levers, e, and f, respectively, are provided for working these aforesaid rods.

By means of the rods, 1, 2 and 3, and crank lever, e, the day and night signals of the "up line" may be actuated by either of the levers, B, or, G, while the rods, 4, and 5, connected with the crank lever, f, operate the "down line" signals by the levers, G^1, B^1 or A^1.

Beneath the flooring are arranged two pairs of rocking-shafts, H, H^1 and I, I^1, to which the aforesaid cranks are secured for giving motion to the signal rods.

To the levers, A A^1, are jointed two connecting rods, the one connecting the first lever with the rocking-shaf I,ard the second one, the latter with, I^1.

Assume the lever, B, moved so as to raise the "up line" semaphore, thus indicating that such line is not clear or safe for traffic.

Then, if the lever, A, be moved backwards, the points of the "up line" will be put in motion, so as to effect a communication between the up and branch lines, while the signals will be caused to indicate such condition of the road.

So long as the points remain in this position, the signals of the "up main line" cannot be interfered with or altered, for the lever, G, is locked by the position of the lever, A, and the lever, B, is also rendered inoperative. But, by releasing or returning the lever, A, the points are again closed and ths signals of the "up line" liberated and consequently free to be worked by either of the levers, G, or, B. The operation of parts relating to the "down line" is effected in a precisely similar manner. This was the first piece of apparatus to effect a simultaneous and necessarily harmonious action of the points and signals of a railway junction, the position of the points in all cases dominating the operation of the proper signals.

"SULLIVAN'S PATENT AUDIBLE RAILWAY SIGNAL."

The object of the invention shown on Plate CXLIII., is to produce an audible signal, to be used in conjunction with, and as an auxillary to the ordinary signals.

It consists of a large gong, fixed on suitable frame work, which may, when desired, carry a lamp and disc.

An iron bar is fixed by a spring to the side of the rail of the track, one end of which projects a little above the top, when the ordinary signal indicates danger. But it is drawn below either by a line or by an electric magnet, when the ordinary signal indicates "all clear." A suitable lever is jointed to the highest end of this side rail, and pivoted upon a bracket near it, its outer end forming the head to strike the gong.

Now, it is evident, that when placed as above described, an engine coming along will depress the side rail, and sound the gong, hence the driver's notice is called to it, and if this signal is placed at a proper distance in advance of the ordinary signal post, the driver will have time to stop his train before reaching it, even though he be unable to see it, as in fogs &c. It is proposed to use this invention in foggy weather, as a substitute for the present plan of placing detonating signals upon the rails.

On the other hand, if the side rail be held down, by the means above described, no sound will be produced, when the engine passes, and the driver will then know the line is clear.

This invention has the advantages of being simple and direct acting, which is of primary importance with mechanism of this kind.

REDFERN'S IMPROVED RAILWAY FROG.

This frog, which we illustrate on Plate CXLIII., consists of a metallic bottom or bed-plate, A, to the upper face of which is secured a plank, B, equal equal in length and breadth. At the ends of this plank are fixed transversely two iron plates, C, C, forming chairs upon which the upper part of the frog rests. This consists of a plank, D, likewise having transverse iron plates, E, E, to which the outer ends of the V of the frog and the guard-rails, I, I, are fixed. The V of the frog has two loops, K, K, projecting downwards into a recess in the plank, D, and through these pass the iron plates or keys, F and G, which, being bolted down to the plank, D, keep the V of the frog securely in its position. There is a similar loop.

L, upon each of the guard-rails, and through these the plate, G, also passes, thus securely fixing them.

The substitution of these keys for the ordinary heavy plates gives this frog a great advantage both in weight and cost over the ordinary frog Also, by increasing the elasticity, they increase the durability of the frog, and with this device the removal and replacing of a fractured V-part, or a wing-rail, occupies much less time and labour than is required with the ordinary frog. In a letter from G. Jamnie, Esq., General Manager to the Steel Company of Canada, to the Canadian Frog Company, concerning the behaviour of these frogs, he says:—"The five Railway Frogs obtained from your company during last year have been in our railway tracks very nearly one year, and have proved to be all that you represented. They have stood rather a severe test, being placed in our work-yard where continual shunting with very heavy tank engines is going on night and day. The engines weigh thirty-seven gross tons, and under their weight, and the great traffic, they have proved perfectly efficient. During the winter they have given far less trouble, by icing, than the other frogs."

(*To be continued.*)

WEBB'S THREE-CYLINDER COMPOUND LOCOMOTIVE "EXPERIMENT."

THIS engine, Plate CXL, which has been built at the Locomotive Works, at Crewe, by Mr. F. W. Webb, was designed by him with a view to the more economical working of the locomotive and to ascertain if the compound principle could be adapted in its present form without undesirable complications, at the same time to do away with coupling rods. In the engine under notice these objects have been attained with complete success.

Soon after leaving the shops, the engine was put in the traffic as assisting engine to a very heavy train from Crewe to Euston, and the next morning took the 7.15 Irish mail from Euston to Holyhead, arriving there at 1.40, and leaving again at 3 o'clock with the boat express, arrived back at Crewe at 6.3, a total distance of 528 miles. During the whole of the journey the engine maintained itself well in steam, the consumption of coal being 23½ lbs. per mile, including that for raising steam.

The following are the leading particulars of the engine:—

HIGH PRESSURE CYLINDERS (outside)—

Diameter...	11½ in.
Stroke of piston	24 in.

LOW PRESSURE CYLINDER (inside)—

Diameter...	26 in.
Stroke of piston	24 in.

WHEELS—

Diameter of leading wheels (radial) ...	3 ft. 6 in.
Diameter of front driving wheels (low pressure cylinder)	6 ft. 6 in.
Diameter of hind driving wheels (high pressure cylinder)	6 ft. 6 in.
Distance between front driving and hind driving wheels	8 ft. 3 in.
Distance between leading and front driving wheels	9 ft. 4 in.
Total wheel base	17 ft. 7 in.

BOILER—

Length of boiler barrel	9 ft. 10 in.
Mean diameter of boiler (outside) ...	4 ft. 1¼ in.
Length of tubes between tube plates ...	10 ft. 1 in.
Diameter of tubes outside	1⅞ in.
Number of tubes	198

HEATING SURFACE—

Firebox	103.5 sq. ft.
Tubes	980 ,,
Total	1083.5
Area of Firegrate	17.1

Weight of the engine in working order is about 36 tons, of which there is 13 tons on each pair of driving wheels.

We shall publish at an early date detailed drawings and descriptive matter.

CORRESPONDENCE.

Laleham, Polworth Road,
Streatham, S.W., *Feb. 6th*, 1882.

To the Editor of the "RAILWAY ENGINEER."

SIR,—The late serious accidents induce me to draw your attention to my proposal annexed.

In support of it I quote Mr. Chamberlain's words on railway accidents (to a deputation):—"In his opinion as Parliament had given the Railways enormous powers and privileges, the public had a right to claim from Parliament that some means should be devised for the protection of the public."

Let the Passenger Duty then be abolished, but let there be *some return* for these *enormous powers* and *privileges*, *i.e.*, some *clear* and *effective means* for checking the number of accidents.

And such, Sir, I submit, is the scheme I now propose.

The *Substitution* of a Tax on Railway Accidents for the Passenger Duty.

The *Scale* to be £2,000 for every passenger killed, and £500 for every passenger injured from causes beyond their own control.

For example, from the Board of Trade Returns in the United Kingdom, there were—

In year 1876:—

Passengers, 36 killed	...	£72,000
,, 1,245 injured	...	622,000
Total Tax	...	£694,000

In year 1877:—

Passengers, 11 killed	...	£22,000
,, 664 injured	...	332,000
Total Tax	...	£354,000

In year 1880:—

Passengers, 29 killed	...	£58,000
,, 904 injured	...	452,000
Total Tax	...	£510,000

In no case, however, shall the yearly tax on any Company exceed a 5 per cent. Passenger Duty, levied as now. The Passenger Duty now produces £700,000 a year.

A glance at the above scale will show how great the inducement will be to keep down the number of killed and injured.

I am, Sir,
Yours faithfully,
R. V.

OFFICIAL REPORTS ON RECENT ACCIDENTS.

COLONEL RICH has reported the result of his inquiry into the circumstances which attended the accident that occurred on the 27th August last, on the Severn and Wye Railway. The train due to leave Lydney at 4.45 p.m. got off the rails, while running between Whitecroft and Parkend stations. The accident appears to have been caused by the flange of the right leading wheel of the engine catching the inside edge, and mounting the right side rail. The inside of this rail was much worn and jagged. It should have been turned or replaced with a good one. I noticed several other rails on this section of the Severn and Wye Railway which should be removed, as they are much worn. The "Robin Hood" engine, that got off the rails, cannot be a very steady engine at any time when running fast, and more particularly so when attached to a light train, as it was when it mounted the rails. It has outside cylinders, a very short wheel base, and very short springs. The engine was in good order.

MAJOR-GENERAL HUTCHINSON has also reported the result of his inquiry into the circumstances connected with the accident and collision which occurred on the 11th August last near Abbey Hill junction, Edinburgh, on the Edinburgh and Berwick section of the North British Railway. This collision resulted from the inability of the guard in the rear brake-van of the East Coast down express train to stop the rear seven vehicles after that they had broken away from the front of the train upon its again starting, just after having been stopped at the Waverley station down home-signal. The coupling between the tenth and eleventh vehicles gave way when the rear part of the train was standing in the Calton tunnel (405 yards long), the rear van being about 125 yards from its western mouth. The ringing of the bell in the van (by the snapping of the communication cord) was the first intimation the guard had of anything being wrong, and for a short time both he and a detective policeman, who was with him in the van, were uncertain which way the van was moving. The doubt was, however, quickly removed on their seeing daylight at the east end of the tunnel, and

the van brake was then applied, and was, it is stated, fully on just as the van emerged from the tunnel; shortly after which the Pullman car brake is also stated to have been applied by the conductor; the speed, however, had become too great for these measures to control the speed of the seven vehicles, weighing probably about 110 tons, on the falling gradient of 1 in 78, and the whole continued to move eastward, at a speed not exceeding, it is stated, about ten miles an hour, till they met (after having run back a total distance of nearly 1,000 yards, passing on their way Abbey Hill junction, 635 yards from where the van started), a special train from Musselburgh, which was pulling up at the Abbey Hill junction signal, and had just stopped dead, its driver having first caught sight of a man running back, and then immediately after of the runaway vehicles, when probably nearly 200 yards off, a curve in the line and a high wall having prevented his seeing them previously. The breaking of the coupling (which, as before described, had a concealed flaw), was caused by the sudden stop and start on the incline of 1 in 78, and it is probable that the strain upon the couplings may have been increased by the train driver not having given sufficient time for the release of the air brake (which had been used for stopping at the home-signal,) upon the rear vehicles when starting so immediately after stopping. An automatic brake would, in this case, have been of great service, as the brakes on five of the rear seven vehicles (two not being connected) would have been at once brought into play upon the severance of the couplings taking place, and these vehicles would have been immediately stopped. The driver of the Musselburgh train appears to have acted promptly on seeing the plate-layer running and then the runaway vehicles. With a continuous brake he would no doubt have been able not only to have stopped, and also to have got into backward motion before the collision, and thus have mitigated its violence. As it was, his train was ill provided with brake-power, there having been only, in addition to the steam-brake on the engine and a hand-brake on the tender, one guard in the rear van with a train of twelve vehicles. The defective coupling had, I understand, been in use for about three years, and was of the strongest form now made by the Great Northern Railway Company, who maintain the East Coast Joint Stock; the strength of these couplings has, it is stated, been considerably increased since the introduction of continuous brakes. The flaw in the present case should, as it appears to me, have been seen when the coupling was being originally made, though after it was once painted it would not have been visible when examined, as it is stated to have been, a week before the accident. In consequence of the falling gradient of 1 in 78, which prevails from near Waverley station for a long distance eastwards, it is very desirable that runaway points should be introduced on the down line not less than the longest train's length east of the down home-signal. As it would be inexpedient to have them in the Calton tunnel, I would suggest their being placed between its eastern mouth and the down advance-signal at Abbey Hill junction.

Major Marindin has reported the result of his inquiry into the causes of a collision which occurred at Lewes station, on the London, Brighton, and South Coast Railway, on the 23rd of August last. Ganger Blackman in his evidence describes very clearly the events preceding this collision, which was undoubtedly due to a grave mistake on his part. He ought not to have allowed any of his gang to get off the trolleys to pick up their clothes until these had been brought quite to a stand, and had been properly secured. I believe, however, that the two leading trolleys would not have started off and overpowered the men who remained, one upon each of them, if it had not been for the carelessness of the two men remaining on the rear trolley, in letting this one strike the one in front, and so start it off. The probability is that all the men were in a hurry to get home from their work, and, as is unfortunately too often the case in these days, were thinking more of this than of doing their work properly. After the trolleys had got away, the ganger and the man on the second trolley seem to have done their utmost, with the means at their disposal, to bring them to a stand, and the ganger remained at his post until the collision was inevitable. It might easily have been averted if it had not been for a mistake on the part of the signalman at Ashcombe or at Lewes. There was certainly a message sent from Ashcombe to say that three trolleys were coming down, and were to be turned on to the Tunbridge Wells line; but while the Ashcombe signal man states that he sent another message to say that the men on the trolleys were unable to stop them, the signal-man at Lewes denies having received any such message. The probability is that the statement of the latter is correct, for the Ashcombe signalman admits that he did not obey the rule as to entering the messages at once, and, if this message had been sent, there could have been no possible reason for the Lewes signalman not attending to it. There is no signal in the block telegraph code in use on this line for vehicles running away, as the company consider that there is less liability of mistake when such messages are sent on the speaking instrument, in the use of which all their signalmen are instructed. Although the results of this collision were not grave, there can be no question about the real danger which is caused by the run-ning away of heavily laden trolleys on a steep incline, and I think that the Company would do well to issue some regulations regarding the use of trolleys, and limiting the loads which may be placed upon them. Trolleys cannot be dispensed with in carrying on the ordinary repairs of a line, but it would be far better in such cases as this, where it appears that over 50 tons of rails had to be moved, to em-ploy ballast trains, using trolleys only in cases where a few

rails or some light loads have to be moved. It is also worth consideration whether platelayers' trolleys should not be fitted with a proper brake, provided one could be designed strong enough to stand the rough usage to which such trolleys are necessarily subjected.

Colonel Rich has also reported the result of his inquiries into the circumstances attending the collision which occurred on the 5th September last, at the Abingdon station of the Great Western Railway. The accident was caused by the engine driver not checking the speed of his train in sufficient time. The train consisted of about three more coaches than usual, and was well loaded with people returning from St. Giles' Fair at Oxford. The night was dark, and it was raining slightly. The driver is not a registered driver, but has been a long time a fireman, and he has been driving this train as a relief-man for the past ten months. He excuses himself for the mistake he committed by saying, that the train was heavier than usual, that the rails were greasy, that the wheels would not bite, and that he did not know he was coming too fast until he reached the signal, which is only 370 yards from the end of the station platform. The tank-engine which he was driving is provided with brakes on the leading and driving wheels, which would exert a large amount of stopping power if applied properly and in sufficient time. It is desirable that a second or distant signal should be provided for Abingdon station, and that the points and signals should be interlocked and worked from a raised cabin.

Major-General Hutchinson has also reported the result of his inquiry into the circumstances connected with the accident which occurred on the 23rd September last, at Carrigtwohill station on the Cork and Youghal Branch of the Great Southern and Western Railway of Ireland. It is not easy to account for this accident, in which the left wheels of the engine and van next to it of the 2.35 p.m. passenger train from Cork to Queenstown got to the wrong side of the left switch of the facing-points of the loop line at Carrigtwohill station, while the wheels of the three following carriages kept the proper rails. There is no reason to doubt but that the points were properly padlocked and admitted only of a slight opening between the left switch and the stock rail. The switches were in excellent order, and although there was no gauge-tie, there was no tendency (the fang-bolts being quite tight) in the gauge to spread. The gauge was slightly slack, about a quarter of an inch. The mark of a blow on the tip of the left switch (which is stated to have been bright just after the accident), the marks after this being on the bolt heads of the fish-plate between the heel of the left switch and the stock rail, together with the driver's statement as to what he felt on the engine, lead me to believe that from some unascertained cause the left switch could not have been quite close to the stock rail, but was sufficiently far from it to enable the left leading wheel of the engine (which from the curve would have a tendency to hug the left rail, and the lip of the tyre of which was very sharp) to strike the tip of the switch, then to mount it, and thus to force it sufficiently open to allow probably the rest of the left wheels of the engine and the left wheels of the van to insert themselves between the switch and the stock rail; the switch then closing and allowing the left wheels of the remaining carriages to keep the proper side of it. The engine which thus left the rails was No. 38, a four-wheeled coupled tank engine, with a four-wheeled trailing bogie. Its weights when weighed at Inchore after the accident, were as follows:—

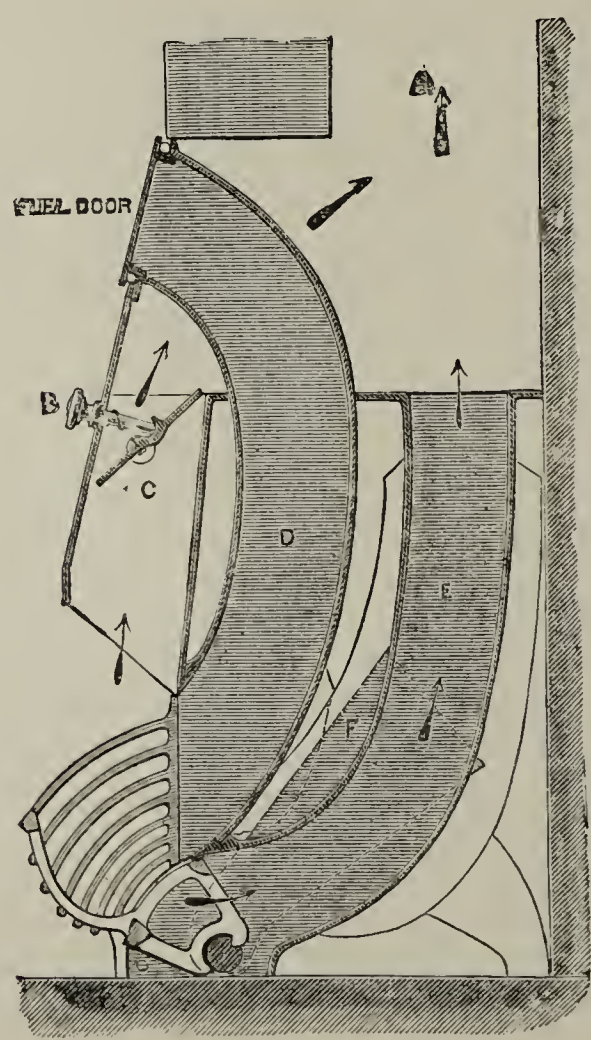
	Right.		Left.		Total.	
	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.
Leading wheels	4	1	5	12½	9	13½
Driving "	7	7	6	1½	13	8½
Bogie "	—		—		16	10
					39	12

The engine having run about 50 yards over the sleepers, its weights may have been deranged, otherwise the inequalities of the weights on the right and left leading wheels, and on the right and left driving wheels, amounting to rather more than 1½ tons, and 1¼ tons respectively, combined with the relative lightness of the leading wheels, would tend to make the engine unsteady and ready to mount on meeting with any slight provocation. It seems probable that this accident would not have happened, if, first, the left switch of the facing-point had been close to the stock rail; if, second, the left leading tyre of the engine had not been sharper than is customary, and thus more ready to strike the tip of a not perfectly closed switch; and if, third, the engine had been heavier in front and more evenly weighted than was probably the case, as it would then have been less likely to have mounted, on the left wheel striking the left switch. The accident would probably not have occurred had the facing-points been provided with a locking-bolt interlocked with the signals.

Major-Marindin has also reported the result of his inquiry into the causes of a collision which occurred on the 10th September last near Marchmont Station, on the North British Railway. The evidence in this case is very conflicting in many important points, and upon some of it very little reliance can be placed. According to the statements of the men with the passenger train, they left Dunse at 9.55 a.m. and Marchmont at 10.5, and the collision took place at 10.10 or 10.11. The evidence of the men with the goods train would put the collision at a later hour, for they state that they passed Marchmont at 10.12, having left Dunse at 9.55. The evidence of the station-master at Marchmont gives the time of the leaving of the passenger train at

10.1, and of the passing of the goods train as 10.12; and the evidence of the signalman at Dunse gives the starting of the passenger train as 9.50 and of the goods train as 9.58. To this last man's evidence I attach no importance whatsoever, for the entries in his record book have clearly been tampered with, and I have very little doubt that the times given by the men with the passenger train are nearly correct, although the time of the collision was probably a minute or two later than they say. However this may be, it is unfortunately apparent that this collision was due to serious breaches of the rules by more than one of the servants of the Company. In the first place, the goods train ought to have stopped at Marchmont, as the statement of the driver that he received a signal from the station-master to proceed is clearly incorrect, and he admits that he passed Marchmont three minutes before he was due to leave; for which he is much to blame. In the second place, the station-master at Marchmont admits that he lowered the signals for the goods train only eight minutes after the passenger train had left, and in so doing he acted in contravention of rule 161. There is no fault to be found with the action of any of the servants of the Company who were with the passenger train; but I think that the driver of the goods train, knowing that he was running before his time, close behind a passenger train, and upon a line where the sharp curves prevented him from seeing far before him, ought to have been even more than usually careful not only to keep a good look-out himself, but to see that his fireman also was doing so, in which case the passenger train, or the guard of this train, who was running back, would have been seen sooner, and in time for the speed of the goods train to have been considerably reduced before the collision took place. The best remedy for accidents such as this would be the adoption of block telegraph working, without which no new lines are now allowed to be opened; but until this has taken place very stringent measures should be taken to ensure that all breaches of the rules for working lines which have not the advantage of the block system should be detected and punished, for upon a strict and literal adherence to these rules the whole safety of the public travelling upon such lines depends.

The "Wonderful" Grate.—There is nothing more important at the present time than to have a perfect control of the ventilation, not only of private houses, but also of those public refreshment-rooms at which railway passengers are sometimes compelled to stop, and, perhaps, at the risk of catching, if not an infectious disease, a cold, which may lead to fatal results. We illustrate a remarkable grate which is intended to improve the ventilating and warming of rooms. In the first place, from the construction of the *grate proper*, the fire surface can be regulated at pleasure, or, in ordinary language, the apparent fire may be made larger or smaller at will. In the second place, the fire being fed from the back, there is no dust, such as is caused by *throwing* coals on a fire in the ordinary way, and this feed being arranged through a coal hopper, which requires charging only once in twenty-four hours, no personal attention is required from one morning until the next. The value of such a grate in large public rooms can hardly be overrated. In the third place, the perfect control of the ventilation of the apartment is of great importance, this control being afforded by the provision made for causing the draught from the grate proper to flow either upwards or downwards, the course of the draught being regulated by a small handle in front of the stove. If the draught is entirely upwards, ordinary slow combustion ensues, as in an ordinary grate, but by closing the damper, and causing downward draught, intense combustion is induced, a clear uniformly glowing fire resulting. The adoption of this apparatus in the waiting rooms of railway-stations would, we think, give satisfaction to both passengers and proprietors, as requiring attention only once in twenty-four hours, the company's servants would not only be saved a troublesome work, but the passengers would also be comforted by a uniform glow of warmth, adjusted to the normal temperature of each day, and so kept.



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THE PROJECTION AND CONSTRUCTION OF RAILWAYS—COMMERCIALLY AND PRACTICALLY CONSIDERED.

(*Continued from page* 67.)

TO give here in detail the formula for determining the various elements of oblique arches, semi-circular or segmental, and the practical methods of working the stones, would be a work of supererogation, as they are fully set forth and demonstrated in Mr. Buck's well-known treatise, with which the young railway engineer should make himself thoroughly conversant—not a difficult matter by the way; for, although the formula *look* portentous, the whole demonstration requires for its comprehension nothing beyond a knowledge of simple trigonometry—the "arithmetic of sines," as Mr. Buck very aptly termed it.

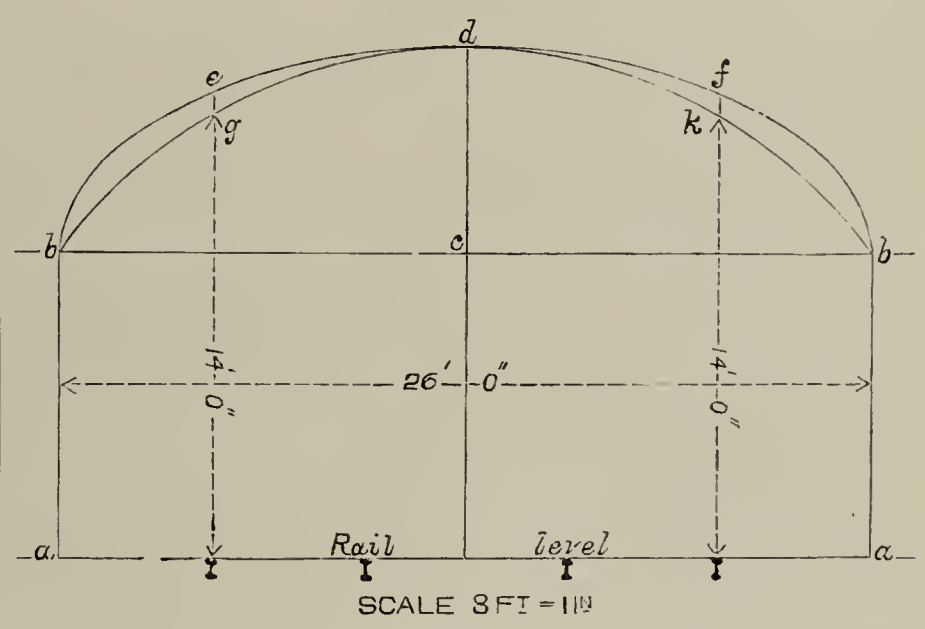
In entering upon the consideration of oblique arches *elliptical on the square*, this question may naturally arise—what is the advantage, or where the necessity of constructing an arch elliptical on the square, if it be not for the sake of appearance? We, therefore, point out how in some cases the use of an elliptical arch may save the expense incurred by the adoption of an iron bridge.

The stability of the elliptical arch may be called in question, but in ordinary railway practice the backing at the haunches has a very material effect on the stability of the structure. In cases where the general contractors for a line have simmered up from the "navy" class there may be a doubt in the engineer's mind as to their competence to deal with anything out of the ordinary everyday work of segmental arches; but the writer has known of one case in which a square elliptical arch was so built, the contractor who constructed it expressing a hope (nineteen years after the completion of the work) that he might suffer eternal torments if it were not yet standing. We have not used the exact words employed by the contractor referred to, but have endeavoured to convey his meaning. This evidently shows that the arch in question was built at hap-hazard, and that it is another illustration of the observed fact that it is somewhat difficult to erect an arch of small span, which shall not be sufficiently stable to sustain its superincumbent load.

The advantage, then, to be gained by the use of an elliptical arch is an increase of headway, a most important matter in many cases for bridges both over and under a railway.

We take as an example the case of a bridge over a double line of railway, as illustrated in Fig. 29.

FIG. 29



The least headway permissible over the outer line of rails is 14 ft. to the soffit of the arch, this being the ruling measurement. The width between abutments is 26 ft., and the rise of the arch one fourth the span, that is 6 ft. 6 in.

The line, *a,a*, shows the rail level, and the arc, *b,d,g,h,d*, the soffit of a segmental arch satisfying the conditions of 14 ft. clear headway at *g* and *h* points over the outer rails.

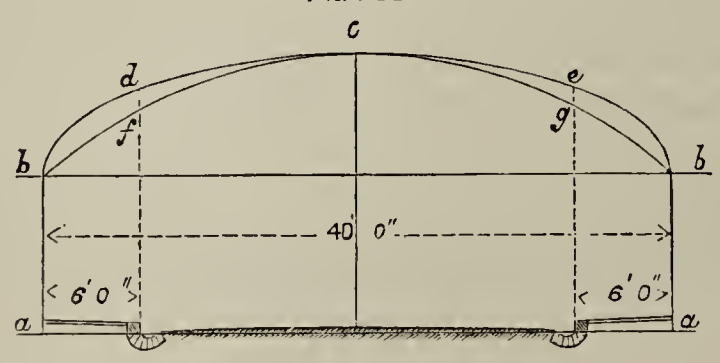
If we describe a semi-elliptical arch having the same span, *b,b*, and the same rise, *c,d*, the soffit becomes of the form shown by the curve, *b,e,d,f,b*, and at the point, *e* and *f*, immediately over the outer rails there will be a clear

headway of 14 ft. 10 in.; hence, we can lower the arch 10 in., a matter of no small importance when we are tied for head room.

We will show how this may affect the question of bridge approaches. Assume that the bridge is designed to carry a turnpike road, and that powers have been taken to raise it at the point where it crosses the railway, the approaches must be made on gradients not steeper than 1 in 30; hence, the difference of length of approach on each side of the bridge corresponding to the 10 in. of headway will be 25 ft., a distance often of very great moment in regard to the property on either side of the railway.

If, on the other hand, the bridge carries the railway over a road, a similar advantage is gained by using the elliptical form of arch, as it affords a greater headway towards the sides of the road, and, therefore, increased facilities for traffic, especially on such roads as are traversed by wagons carrying high loads.

FIG. 30



SCALE 16 FT = 1 IN

Fig. 30 illustrates circular segmental and elliptical soffits for an arch over a road 40 ft. wide, having footpaths on each side 6 ft. wide.

a,a, is the road and footpath surface, *b,f,c,g,b*, the circular soffit, and *b,d,c,e,b*, the elliptical soffit.

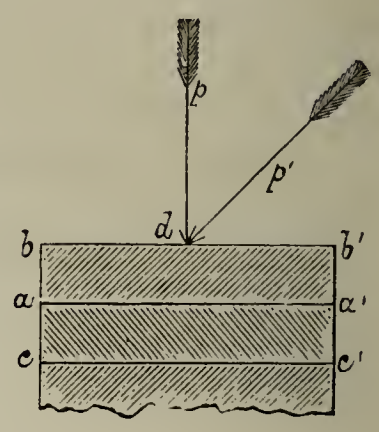
It will be found that by adopting the elliptical soffit we gain upwards of a foot in headway over the line of kerb. Considering that heavily laden wagons in large cities usually keep the side of the road, it is at this place that the greatest headway is required.

The foregoing remarks showing the advantage of an elliptical arch over a roadway apply probably with even more force to the case of a bridge over a navigable river, where, under some circumstances, it becomes necessary to run as close as possible to the pier of a bridge. As an instance, we will refer to an accident that occurred about fifteen years since on the Thames, when the lowered funnel of the *Fairy* came in contact with one of the arches of Southwark Bridge. Had that arch been elliptical the funnel would have cleared it. It may be added that this accident occurred under the personal observation of the writer, and that an extra headway of 6 in. would have allowed the *Fairy* to clear the arch.

In setting out the courses of brickwork or masonry for any structure it must be borne in mind that the joints should be as nearly as possible at right-angles to the line of thrust; in any arch all the lines of thrust are parallel to the face of the arch; hence, the coursing joints should be as nearly as possible at right angles to the face of the arch.

We will here point out the reason for so arranging the joints in regard to the thrusts passing through them.

FIG. 31



In Fig. 31 *a,a'*, shows a joint between two stones, *a,b,b',a'*, and a lower stone, *a,c,c',a'*. In joints of this description no reliance should be placed upon the mortar uniting the stones, for even if it is of good quality it will take several years to set, and some of the best prepared mortars have never set throughout the bed, the chemical action upon which their induration depends having rendered the faces of the joints impervious to atmospheric air, and, therefore, preventing the access of carbonic acid to the interior of such joints; this non-setting of the mortar in the central parts of the beds has been observed in making alterations in buildings dating from the time of Vitruvius.

To return to the consideration of the *stability* of the joint *a.a'*, let there be a thrust, P, acting upon the stone *a,b,b',a'*; this thrust acting at right angles to the joint *a,a'*; we assume that the amount of thrust is within the safe working strength of the material used, so that we have only the question of stability to deal with. So long as the thrust is at right angles to the joint *a,a'*, it is evident it will have no tendency to *slide* the stone *a,b,b',a'* upon the stone beneath it, but if the direction of the thrust be inclined there will accrue a tendency to slide the upper stone upon the lower, and when the inclination attains a certain angle (varying with the materials dealt with) such sliding will occur.

If the inclination of the line of thrust at which the upper stone will slide upon the lower be indicated by the arrow, P', then the angle *P,d,P'* is termed the limiting angle of friction, and this should not only not be exceeded but the angle of the line of thrust with the normal *P,d* should never exceed one-third of the limiting angle of friction. The following tabulated form shows the limiting angles of friction for various building materials:—

Masonry	31 to 35 deg.
Damp Masonry	36½ ,,
Timber on Stone	22 ,,
Masonry on Clay	27 ,,
Soft Dressed Stones	36½ ,,
Hard ,, ,, ...	37 ,,
Common Bricks	33¾ ,,
Hard Calcareous Stone	35 ,,

In almost all cases, even where stone abutments are used, it is customary to turn the arches in brick, the face vous-

soirs alone being of stone, in order to accord in appearance with the facework of the abutments; usually there will be an ample margin of strength, but occasionally it becomes necessary to employ very flat arches, such, for instance, as some that have been constructed with a rise of only one-ninth of the span. We, therefore, append the results of some special experiments upon different kinds of bricks, these experiments having been conducted by Mr. David Kircaldy, in 1874, in order to determine the relative values of certain bricks proposed to be used in the construction of some branch lines of railway in the midland counties :—

AVERAGE RESISTANCE OF BRICKS TO CRUSHING.

Description of Brick.	Area.	Cracked	Cracked g'nerally	Crushed
	Sq. In.	Tns. per Sq. Ft.	Tons per Sq. Ft.	Tns per Sq. Ft.
Recessed Red Brick, Morand's Machine	36.86	86.8	108.1	161.6
Wire-cut Red, Porter's Machine	32.61	104.5	155.4	228.1
Recessed top and bottom red, Scholefield's Machine ...	39.95	120.9	157.1	192.4
Wire-cut red, Johnson's Machine	39.17	125.8	177.8	233.0
Red Brick, ground in mortar mill	37.82	143.9	180.3	200.3
Red Brick, pugged in pug mill	38.12	92.7	119.7	163.2
Red Brick, Bulmer's Machine	34.29	109.6	157.4	220.4
Recessed Reddish Brick, Nottingham Patent Brick Company	40.34	152.1	180.4	204.9
Smith's Red Brick	37.87	46.5	57.9	64.2
Cowley's Stock Brick	37.70	43.4	54.7	56.6
Burham Gault Brick Wire-cut	40.37	75.6	114.8	114.9
Blue Staffordshire Brick ...	39.23	136.3	210.9	254.7

In order to determine the direction of the coursing joints of the bricks or stones in the arch, we must prepare a "development" of the soffit or intrados of the arch, and also a development of the extrados or outer surface of the arch. A development of a curved surface shows that surface as it would appear if *unrolled* and extended upon a plane surface; the preparation of such developments is sufficiently simple, as will be seen by a reference to Fig. 32. a,b,c, is a section on the square of an oblique arch elliptical on the square; the semi-ellipse, a,b,c, representing the intrados or soffit of the arch, a,c, is the square span. One face of the arch is shown in plan at a,e; a,e, being the oblique face of the arch; draw c,e, at right angles to the chord a,e; then will the angle, θ, be the angle of obliquity of the arch, or, as it is more commonly called, the angle of skew.

We find then from the ordinary principles of trigonometry that the skew span $(a,e,)$ = the square span $(a,e,)$ × cosec, θ, and the obliquity $(c,e,)$ = the square span $(a,c,)$ × cotan, θ.

Produce the chord a,c to d, making c,d equal to the semi-ellipse, a,b,c. The length of the semi-ellipse will be found from the formula,

$$c,d, = 1.5708 \sqrt{\frac{a,c,_2}{2} \times 2(bh)^2}.$$

The semi-ellipse, a,b,c, is now to be divided into any convenient number of equal parts measured upon the periphery, and these measurements should be made as small as is convenient, in order to approximate closely to an absolutely accurate division of the semi-ellipse, for the shorter the chord of each arc the more closely will the length of the arc approximate that of the measuring chord.

In the figure the semi-ellipse is shown divided into 24 parts, and in like manner the line, c,d, is to be divided into 24 equal parts. From the divisions 1, 2, 3, &c., in the semi-ellipse, a,b,c, let fall straight lines parallel to c,e, (and therefore at right angles to a,e,) until they meet the straight lines, a,e; then from the points at which these vertical lines meet the line, a,e, draw lines parallel to a,c,d, as shown; from the divisions 1, 2, 3, &c. on the line c,d draw, as shown, lines parallel to c,e, until they meet the lines last referred to, drawn parallel to a,c,d; the intersections of these lines will give points in the face line, e,f,g,d, of the development of the intrados of the arch.

If W be the width of the arch, then a,e,l,k will be the plan of the intrados of the arch, and completing the development from the face line k,l we get for the remaining face of the arch the line, l,q,r,m, and the complete development of the intrados of the arch is shown by the figure, l,e,f,g,d,m,r,q,l, and upon this development the intradosal coursing joints must be arranged.

Join e,d, and from e, at right angles to e,d, draw the straight line e,n, then the angle, α, between the lines l,e, e,n will be the theoretical angle at which the courses should rise from the impost on the intrados, this angle satisfying the condition that the joints shall be at right angles to the line of thrust.

It will, however, be seen that we cannot always work to the theoretical line of coursing joints, hence we must approximate as closely as is practicable to it, and this we can always do without materially approaching the limits of inclination prescribed above.

We here take the case of an arch on stone abutments with stone voussoirs on the faces of the arch, the intervening space being made up with brick work.

The term spiral used in connection with oblique arches circular on the square cannot be correctly applied to such arches elliptical on the square, hence we must adopt different expressions, and we shall in this investigation adopt the terms, inclination of courses, and inclination of heading courses, and length of heading course.

The length of the heading course is that of the line e,d, or l,m, and this line must be divided into a suitable number of parts to fit the courses of brick or stone to be used in the construction of the arch.

We must now prove that the angle, l,e,n, is equal to the angle, c,d,e.

Because c,e,l is a straight line, therefore the sum of the angles, c,e,d, d,e,n and n,e,l, is equal to two right angles; but by the construction, d,e,n, is a right angle, hence c,e,d is the complement to the angle, l,e,n; again, because e,c,d is a right-angled triangle, having $e.c,d$ a right angle, therefore c,e,d is the complement to the angle, c,d,e. Because the three angles of any triangle are together equal to two right angles. (Euclid, Bk. 1, Prop. XXXII.)

But c,e,d is the complement to the angle, l,e,n, therefore the angle, c,d,e, is equal to the angle, l,e,n, or the angle, c,d,e, is that of the inclination of the intradosal coursing joints, that is the theoretical inclination.

We can now determine the value of the theoretical angle α, which is equal to the angle c,d,e.

$$\frac{c\,e}{c\,d} = \tan\alpha. \quad c\,e = a\,c \times \cot\theta. \quad \therefore \tan\alpha = \frac{a\,c \times \cot\theta}{c\,d}$$

but $c\,d = 1.5708\sqrt{\frac{\overline{a\,c}^2}{2} + 2\,(b\,h)^2}$;

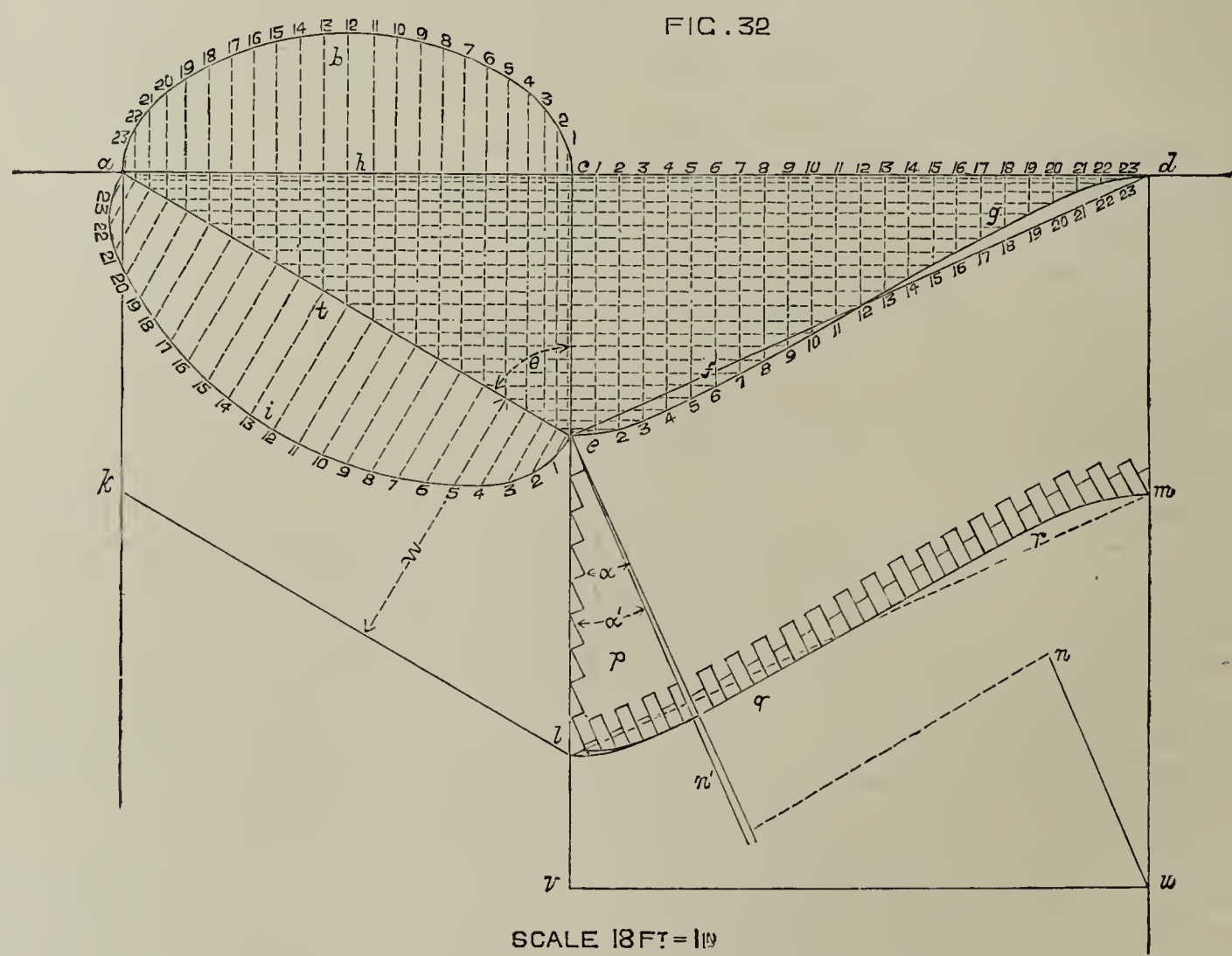
Hence,

$$\tan\alpha = \frac{\overline{a\,c} \times \cot\theta}{1.5708\sqrt{\frac{\overline{a\,c}^2}{2} + 2\,(b\,h)^2}}$$

The length of the heading course $e\,d = c\,d \times \sec\alpha$.

In order to illustrate the practical application of the formula we are now evolving, it is necessary to take an example and work it out in detail, and the more especially,

FIG. 32



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as up to the present time oblique arches elliptical on the square have not been dealt with in a practical way.

Following Fig. 32 we find the square span to be 32 feet and the angle $\theta = 59°, 30'$.

The obliquity $(c\,e) = \overline{a\,c} \times \cot\theta = 32 \times .59 = 18.88$ feet. The rise $b\,h = 10.25$ feet; therefore,

$$c\,d = 1.5708\sqrt{\frac{(32)^2}{2} + 2\,(10.25)^2}$$

$$= 1.5708\sqrt{\frac{1024}{2} + 2\,(105.0625)} = 1.5708\sqrt{722.125}$$

$$= 1.5708 \times 26.87 = 42.207 \text{ feet.}$$

$$\text{Tan } \alpha = \frac{18.88}{42.207} = .4473 \text{ and } \alpha = 24°.\ 6'; \ e\,d = c\,d \times \sec\alpha$$

$$= 42.207 \times 1.095 = 46.217.$$

The heading course, e,d, must be divided into the spaces necessary for the face voussoirs, and each stone must be of such thickness as will fit an even number of courses of bricks.

We prefer an odd number of voussoirs on the face of the arch, as giving greater facility for keying up, and although a female arch may be stable its appearance is hardly satisfactory to the eye of a practical man.

In determining the number of voussoirs on the face of the arch we must be ruled, to a great extent, by the size of bricks made in the district in which the bridge is to be erected. In our example we assume the bricks to be stock bricks, of which four courses average one foot in height (including joints).

Taking, then, four courses of bricks to each voussoir, and forty-five voussoirs on the face of the arch, we have for each voussoir a thickness of 1.027 ft. on the intrados.

The distance, l,s, is termed the divergence of courses, and is equal to the length of impost, e,l, $\times$ sin α.

The length of impost is evidently equal to W $\times$ cosec θ.

Therefore length of impost $(e,l,) = 20 \times 1.16 = 23.2$ ft.

And the divergence will be $23.2 \times .408 = 9.465$ ft.

Referring to Fig. 32 it will be seen that the nearest approximation to the theoretical inclination of the intradosal course will be that according to a divergence of nine voussoirs on the face, which divergence

$$= 1.027 \times 9 = 9.243 \text{ ft.}$$

From this result we can determine the corrected angle of inclination, α', thus :—

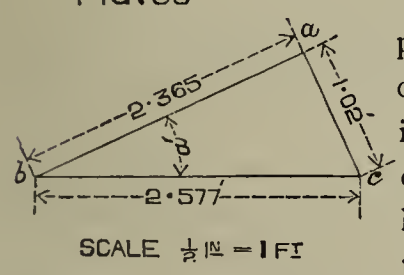
$$\text{Sin } \alpha' = \frac{9.243}{23.2} = .396; \text{ and } \alpha' = 23^\circ\ 19'$$

The number of voussoirs in the face, included between the springing and the corrected line of inclination, e,n', will also be the number of skew backs upon the impost, e,l; hence the length of each skew back will be

$$\frac{23.2}{9} = 2.577 \text{ ft.}$$

Each triangular surface, p, represents the face of one skew back on the intrados, and in order that this may be properly marked on the stone flexible templates must be prepared, made to the corrected intradosal inclination, so that after the springing stones have been wrought to the elliptical profile of the arch (on the square) these templates may adapt themselves to the curved surfaces against which they are laid.

FIG. 33



In Fig. 33 one of these templates is shown ; b,c is the length of templates measured upon the impost ; α' is the corrected angle of inclination. From c a straight line, c,a, is drawn perpendicular to b,a. (Euclid, Bk. I., Prop. XII). We will now determine the values of the lines, b,a, and a,c:

$$b\,a = b\,c \times \text{cosine } \alpha' = 2.577 \times .918 = 2.365 \text{ ft.}$$

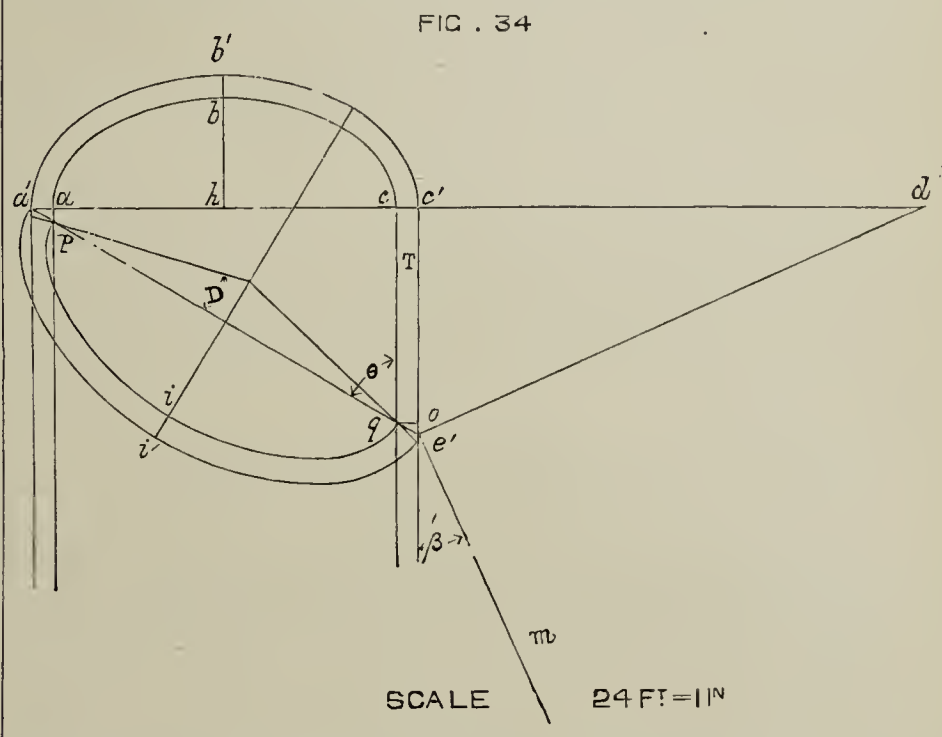
$$a\,c = b\,c \times \sin \alpha^1 \times 2.577 \times .396 = 1.02 \text{ ft.}$$

We will next show the method of projecting the *face* of the arch, so far as the intrados is concerned. Referring to Fig. 32 we have the lines drawn from the divisions 1, 2, 3, &c., on the semi-ellipse, a,b,c, and parallel to the line, c,e, meeting the straight line, a,e; from these points draw straight lines at right angles to the line, a,e, and upon the ordinates so drawn mark off lengths equal to those between the semi-ellipse, a,b,c, and the straight line, a,c; for instance, make $t,i = b,h$, and so forth; then a,i,e will represent in elevation the intrados of the face of the arch. It will now be necessary to prepare a development of the extrados of the arch.

This will be drawn in a manner precisely analagous to that pursued in drawing the development of the intrados, hence the method will not here need illustration, but we can *calculate* the necessary elements, as in the case of the intrados.

In Fig. 34, a',b',c' shows the extrados on the square, the

FIG. 34



letters a,b,c showing the intrados, the same as in Fig. 32. We will first determine the lengths of the semi-ellipse a',b',c', which will give the length of the line, c',d', the formula to be used will be analagous to those employed in the case of the intrados. The thickness of the arch is taken as 2 ft., hence a',c', = 36 ft., and $b',h = 12.25$ ft.

$$\text{Therefore, } c',d' = 1.5708 \sqrt{\frac{(36)^2}{2} + 2\,(12.25)^2} =$$

$$1.5708 \sqrt{\frac{1296}{2} \times 2\,(150.0625)} = 1.5708 \sqrt{948.125} =$$

$$1.5708 \times 30.79 = 48.365 \text{ ft.}$$

The length c',e' (obliquity on extrados) $= a',c' \times$ cot. $\theta = 36 \times .59 = 21.24$. Hence tan. angle c',d',e

$$= \frac{21.24}{48.365} = .4391, \text{ and the angle } c',d',e' = 23^\circ,\ 43'.$$

The line e',d' is evidently equal to the line c',d', multiplied by sec. angle c',d',e', or $e',d' = 48{\cdot}365 \times 1{\cdot}0922 = 52{\cdot}824$ ft.

Returning to Fig. 32, it will be observed that the line, e,n, is the development of the curved line of intradosal coursing joints, and it may be produced to meet the line d,m, also produced, when its length will be that of coursing joint passing from one abutment round to the other. Let c,l be produced to v, making $c,v = d,u$, u being the point at which e,n, produced, meets d,m, produced. (In the Fig. the lines c,v and d,n are shown broken off, to save space.) Join u,v, which will be parallel to c,d, then e,v is called the axial length of the coursing joint, which will evidently be equal to u,v, or c,d, multiplied by cotan α.

Therefore e,v, $= 42.207 \times 2.235 = 94.332$ ft., which

will be the axial length for the coursing joints, both intradosal and extradosal.

Having determined the length of the extradosal arc on the square, we can easily find the angle for the extradosal coursing joint, the angle being marked β on Fig. 34.

The axial length being the same in both cases, the tangents to α and β will be in direct ratio to the lengths c,d (Fig. 32), and c',d' (Fig. 34); therefore,

$$\tan \beta = \tan \alpha \times \frac{c',d'}{c,d} = .4473 \times \frac{48.365}{42.207} = .5125 \text{ and}$$

$\beta = 27^0, 8'$.

A template may now be made for working the extradosal surfaces of the skew back, similar to that shown for the intradosal (at Fig. 33), but of course the angle, α', must be replaced by β', which is to be calculated from the *corrected* angle, α', thus:

$$\tan \beta' = .431 \times \frac{48.365}{42.207} = .494; \quad \beta^1 = 26^0 .17^1.$$

From these angles the winding strips can be determined for working the beds in the usual way. The forms of the ends of the face voussoirs on the intrados will be taken from the development (Fig. 32) and for the faces from the front elevation of the arch, a',i,b',i', projected in Fig. 34. On account of the obliquity of the arch it is evident that at the quoins or face springers the extradosal coursing joint will not terminate at the same point in plan as the intradosal coursing joint, hence the face lines of the springers will not be horizontal.

If we draw a horizontal line at springing height and at right angles to the axis of the arch, so that it touches the face voussoir where its lowest face corner is in contact with the springer, it will be seen that a certain horizontal distance intervenes between this point and the termination of the extradosal coursing joint corresponding thereto, being equal to the distance, o,e', or a,p (Fig. 34).

The angle o,e',q is equal to the angle θ (Euclid Bk. I. Prop. XXXIII), hence if T be the thickness of the arch o,e' will be

$$= \text{T cotan } \theta$$

and this will be the length on which is to be calculated the elevation of the outer end of the springing joint on the face, which elevation will therefore be

$$= \text{T cotan } \theta, \tan \beta'.$$

Producing the springing lines towards the centre of the arch they will intersect at a point below its axis, and from this point the face joints should be made to radiate. It is required to find the distance of the point in question below the axis or springing line of the arch.

By similar triangles we have, calling D the required distance,

$$\frac{h,c}{\text{T}} = \frac{D}{\text{T cotan } \theta, \tan \beta'}, \text{ therefore, } D = h,c, \times \text{cotan } \theta, \tan \beta',$$

which in the example taken becomes

$$D = 16 \times .59 \times .494 = 4.663 \text{ feet.}$$

We have entered very particularly into the case of the skew arch, elliptical on the square, as so far as we know it has never been dealt with before, or if treated the results have not been put at the disposal of the public.

Arches formed on the square of elliptical segments do not command our attention, as there is scarcely anthing to be saved in headway by their adoption, it being in the form of the haunches that the advantage is to be found.

The quoins at either end of the face of the skew arch are termed the acute quoin and the obtuse quoin, the relative position depending upon the direction towards which the arch skews; thus, if as we stand facing the arch the road through it inclines to the left, the acute quoin will be on the left hand of the observer, and the obtuse quoin on his right, and *vice versa*.

When the angle and skew reaches down to, or is less than 45 degrees, the acute edges should always be chamfered off, giving the arch a bell-mouthed appearance, and if the stone of which it is constructed is of a friable character bell-mouthing should be resorted to wherever the angle of skew is less than 50 degrees.

It may be advisable to explain what is accurately termed the angle of skew of an arch, as our younger readers might be mislead into serious errors by taking it to be (adopted in some books purporting to render assistance in Parliamentary Estimates) the number of degrees by which the road under the arch differs from a line at right angles to the road over the arch; of course, such an error would throw all the calculations wrong.

The angle of skew, then, is the angle contained between a line drawn through the axis of the arch at a line drawn parallel to its face.

Various methods of bell-mouthing have been, from time to time, suggested, but some are very costly and others unsatisfactory.

In pursuing the method, shown by the late Mr. Buck, no doubt the most precise course is followed, but as it involves the erection of a scaffolding at each face of the bridge additional expense is incurred without any apparently adequate results; at least, that seems to be a very usual opinion in these days of skimping the cost of structures, although a corresponding parsimony is not shown in matters of Parliamentary Expenses and certain kindred outlets for the revenues of railway proprietors.

A course we have ourselves used with perfect success is as follows:—The general elevation of the face of the arch having been drawn in the usual manner, by projecting it from the square section, a distance is measured horizontally on the face of the acute quoin from the intrados outwards, this distance being such as will allow an additional apparent span capable of admitting *one more voussoir* than the number actually composing the arch. From the point so, found a line is drawn at the springing level horizontally, and at right angles to the face of the

arch, and produced indefinitely. Then, starting from the obtuse quoin at springing level, a line is drawn horizontally along the intrados and produced until it meets the line above mentioned. On the intrados of the arch is drawn a line parallel to the face, and at a distance from the face equal to the width of the portion cut off from the acute quoin by the line drawn at right angles to its face. Then, assuming an imaginary line to be drawn from the intersection of the two produced horizontal lines through the intrados of the centre voussoir of the farthest face, so as to cut it in the line marked on the intrados, and therefore at a distance from the face equal to the width of the portion cut off the acute quoin, we can calculate where this imaginary line will cut the face of the centre voussoir, and thus we shall get three points through which may be drawn an ellipse on the elevation of the face of the arch.

Let W = the width cut away at the acute quoin square to its face.

U = the distance measured upon the face of the acute quoin, and corresponding to the introduction of one additional voussoir.

V = the versine or rise of the arch.

L = the distance (on the line drawn horizontally at right angles to the face of the acute quoin) from the face of the arch to the intersection of the two horizontal lines; the one on which this distance is measured and the other that which is drawn along the opposite springing.

l = L—W, and S = skew span.

h = vertical thickness on face of stone to be cut away from the underside of centre voussoir.

It may be here pointed out that the bell-mouthing gradually becomes fainter as we pass round the intrados from the acute to the obtuse quoin, at which it entirely dies out.

Then,

$$h = V \times \frac{W}{l}\,;\ l = S \times \tan\theta$$

$$W = U \times \tan\theta$$

therefore,

$$h = V \times \frac{U \times \tan\theta}{S \times \tan\theta} = \frac{V \times U}{S}$$

This distance, h, having been marked off on the centre voussoir from the soffit upwards, the ellipse above referred to is drawn on the elevation (which should be made to a large scale, say 1 in. per ft.), when the quantity to be cut off at each joint can be scaled off with sufficient accuracy for all practical purposes, and the width, W, being gauged on the soffit of each face voussoir, the stone may be dressed off, and thus each voussoir can be finished in the quarry with perfect confidence that the work will come accurately together when erected. Templates of each bed joint should be furnished to the masons, and also templates showing the shapes of the ends of the face voussoirs on the soffit, and also of their faces in elevation. All the internal heading joints will be dressed square to the coursing joints.

In determining the stability of an oblique arch it must be remembered that the strains run parallel to the face, and, therefore, the lines of thrust must be worked out on a section parallel to the face; and, morever, in cases where we adopt a ratio of rise to span which we have, by experience, found to satisfy the conditions of equilibrium, this ratio will be that of the rise to the *oblique* span.

When the courses rise from the springing at a very steep inclination there is a tendency to push the end skew backs off the impost, and in such cases as the skew backs cannot all be cut out off one stone the various stones of the springers should be secured together by iron cramps leaded in.

It should be made an invariable rule always before commencing the working drawings for an oblique arch to check the angle of skew on the ground, as this class of work cannot be safely tinkered together on the ground; and it also requires very close watching by the resident engineer, in case its execution should fall into the hands of incompetent masons.

Of course, if counterforts are used in the construction of the abutments of skew arches, they should, in plan, be built parallel to the face of the arch if they are intended to assist in resisting the thrust of the arch; but if they are only required to add to the stability of the abutments, as opposed to earthwork behind them (as in a girder bridge), they should be built square to the abutments.

In setting out bridges on the ground, centre lines should be carefully run for the directions of the roads both over and under, these lines being indicated by pegs. From these centre lines the faces and ends of the abutments can be set off, and they will serve to check the accuracy of the work as it progresses; if the wing walls batter on the face their backs should be set out on the ground, as differences of level will not affect the position in plan of a plumb wall, but if the wings are plumb on the face it will be more handy to set out the face line.

If the bridge carries a railway, and at that point the line is on a curve, care must be taken that sufficient width is provided to allow for the curve. Suppose, for instance, the bridge is 70 ft. long, and the line is on a curve of 10 chains radius, that is 660 ft., then the versine of that curve for the length of the bridge will be

$$= \frac{(35)^2}{2 \times 660} = \frac{1225}{1320} = .982 \text{ ft.}$$

So that for a double line, instead of 25 ft., the bridge should have a clear width of 26 ft.

We will now pass on to consider the practical execution of tunnels, works which also cause considerable anxiety when there is cause for doubt as to the nature of the soil to be perforated.

Tunnelling machines have been designed, consisting of frames formed to the section of the tunnel, these frames carrying travelling picks actuated by compressed air; but these machines have not, so far, been found satisfactory in practice, though, it seems feasible that if they were properly designed, and the moving parts made sufficiently steady, that successful results would accrue. But in machines liable to such violent concussions as air picks, the working gears for feed should be tangent screws and worm-racks, and no such *rattletrap gears* as spur wheels and toothed racks; in the latter case the hold is on one tooth only, whereas in the former a bearing on three or four teeth may be obtained.

The centre line of the railway is carefully set out on the surface, and if necessary (supposing the tunnel to be straight) one or more observatories erected on the centre line, for ensuring the exact rectification of the centre line of the tunnel, by means of transit instruments mounted within them. The transit instrument consists of a telescope tube, like that of a theodolite, only generally longer; this telescope is carried on a strong axis at right angles to its length, mounted at each end in bearings, carried on standards of such height as to allow the telescope to be turned completely round in a vertical plane, so that the instrument, once placed in the right line, that line can be set out in either direction without removing the telescope from its bearings. The telescope is furnished with cross hairs, as in the ordinary theodolite.

The telescope tube is connected with its cross axis by a hollow sphere, in which is placed at a suitable angle a small mirror. When the external light is insufficient to illuminate distinctly the cross hairs a light is reflected upon them from the small mirror, the source of light being a lamp attached to one of the standards in such a position as to throw its rays through an opening in the end of the hollow axis on to the mirror above mentioned. The observatory is to be built as follows, being placed on the highest ground in the length of line it is intended to command:—

The structure may be made of timber sufficiently strong to resist such storms as may occur in the locality of its erection, and, according to its height, floors or landings are to be at certain intervals, say every ten or twelve feet, the sides are to be closed in up to the top, so that no wind can get in to shake the apparatus used in observation.

In the centre of the observatory is to be carried up from a solid foundation a very carefully built brick pillar, which may be three feet square at the bottom and about two feet square at the top, being there finished off by a carefully wrought stone, which is to be properly drafted to receive the standard destined to carry the transit instrument. This standard is to be adjusted to an exact level, and then securely fixed in position. If there are more observatories than one, duplicate standards are made and one fixed, as described, in each obvervatory, then the instrument can be taken from one to another as required.

The brick pillar must be carried up clear of the floors and landing stages, and be a quite independent element from the rest of the structure, so as to ensure that no vibration of the outer covering can be communicated to the transit instrument.

Preparations are now made to sink shafts at certain intervals, these shafts serving a double purpose. They furnish access, so that the tunnel may be simultaneously worked at from several points, thus shortening the time necessary to complete the work; a very important matter if we consider the length of time the capital of the proprietors is lying financially idle, and when the tunnel is completed these shafts will serve to keep it ventilated.

The shafts may conveniently be sunk 9 ft. in diameter, and they should be lined with brick steening 9 in. thick, and carried down 3 ft. or so below the level of the floor of tunnel, so as to form a sump in which any water may collect, and from whence, if necessary, it can conveniently be pumped.

We have first to mark the centre line at the bottom of the shafts, and then from those points to set out the centre line as the work progresses under ground. This is easy enough when the tunnel is straight, but demands very close attention when the tunnel is on a curve—most troublesome if it be necessary to make the tunnel on an S curve; but by ordinarily fair management the latter can be avoided.

The shafts being sunk, the first step is to drive a heading the whole length of the tunnel, 9 ft. square being a convenient size for such headings. The headings will require timbering at the sides and top to uphold the earth or rock through which the heading is run; between the uprights and head timbers, and on the outside of them, will be placed boards to support the pressure of the surrounding earth, and if the soil be of a clayey nature it will be necessary to strut the upright timbers at their feet to prevent their being pressed inwards.

The heading must follow the centre line of the tunnel, which is set out from the surface line as follows:—

On timbers at the top of any given shaft a point on the centre line is determined by sighting through the transit instrument, this point being marked by a fine notch on the timber; the points so determined must now be transferred down the shaft to the level of the tunnel floor; it is done by dropping a heavy plummet suspended on a copper wire, passing through the notch in the top timbers, until the plummet has passed the timber at the bottom and come to rest, when the position of the wire can be marked on the bottom timber. Following this course at each shaft, points in the centre line are marked down the heading, and the direction to be followed in running the heading must be determined by the compass. Thus the angle, made by the centre line with the magnetic meridian on the surface,

will supply the datum for starting the centre line of the heading of the tunnel.

The heading being completed throughout the length of the tunnel, and the centre line checked and verified, we can now proceed with the complete excavation of the tunnel, starting from each side of each shaft and also from the ends.

In bricking in the arch of the tunnel under the shafts a suitable curb of stone or iron must be prepared to carry the base of the lining of the shaft.

(To be continued).

LOCOMOTIVE VALVE GEAR.

WE illustrate (Plate CXLIV.) various systems of valve gear. For the drawings and descriptive matter we are indebted to Mr. Frank C. Smith, of the *National Car Builder*, U.S.

In 1820, and later, in the Killingworth engines the valves were operated by a device similar to that shown in Fig. 1. On the main shaft, *a*, an arm, *b*, carrying a pin, *g*, which slipped freely in the slot, *f*, was fixed. As long as the engine travelled in one direction the pin carried the eccentric *c* with it, and the opposite direction was attained by shifting the eccentric, which was loose on the shaft, until the pin, *g*, reached the opposite end of the slot, *f*, when the engine would move in an opposite direction; *d*, *d* being a rocker-arm, and *e* a rod transferring the motion to the valve.

In 1830 the gear shown in Fig. 2 was used by Bury. This also consisted of a loose eccentric stopped by lugs on the shaft, one lever being used to lift out of gear the eccentric rod and another to handle the rocker-shaft. The loose eccentric, however, was not found to be satisfactory, and Carmichael soon after fastened two eccentrics to the shaft, one for each cylinder, as shown in Fig. 3. An eccentric rod, having a double V-hook, *a*, was thrown into gear by means of the tumbling-shaft, *b*, and pin, *c*, the hooks gearing into the pins, *d* and *e*, on the rocker-shaft, *f*. The lead was obtained by the angle of the rod, and definite proportions were neccessary to make this gear equally effective in each motion.

The gear shown in Fig. 4 also had but two eccentrics, one for each cylinder. It consisted of two V-hooks attached to the single eccentric, which were thrown into or held out of gear by the two toes, *a*, *a*, swinging from *b*, and moved by the reach-rod, *c*; *d* and *e* being rocker-shafts, and *f* the valve stem.

In 1837 the Hawthorns, of Newcastle, first applied four eccentrics. This gear is shown in Fig. 5. The hooks geared in from the under side, and the tumbling-shaft extending clear across the engine, operated both sets of hooks simultaneously, the weight of one counterbalancing that of the other. Modifications of this new system followed each other, and differed only in the arrangement. In Fig. 5, *a* is the reach-rod operating the tumbling-shaft *b*, which, by means of the hanger, *f*, operates one hook. The rod, *c*, attached to the tumbling-shaft, *b*, moved the auxiliary shaft, *d*, which was coupled to the other hook by the hanger, *e*. The shaft, *j*, extended across the frames, and a similar arrangement of levers, etc., operated the opposite gear; *k* being the valve stem, *l* the rocker-arm, *i* the crank, and *h g* the eccentrics, which were of course set singly, each with the proper amount of advancement due to the lap and lead. It will be readily seen that in reversing the engine the hook *m* was lowered and the hook *n* raised into gear with the stud, *o*, in the lower end of the rocker-arm, *l*, thus totally disengaging the rocker-arm from the action of the hook *m*, which then swung free from everything and was sustained by the hanger *f*.

Fig. 6 shows another arrangement of the same principles, somewhat simplified as to the hangers, &c.; *a* being the rocker-shaft, *b* one hook, *c* the other, *d* the tumbling-shaft, *e* the hanger, *i* crank-pin, and *g h* eccentrics, the shaft, *j*, extending across and operating similar gear for the other side of the engine.

In Fig. 7 is shown, what was probably the first attempt to do away with eccentrics by operating the valve from a pin on the main rod, by a Mr. Melling, of the Liverpool & Manchester Railway. This consisted of a stud, *c*, fastened to the main rod, *a a*, fitted with a block sliding in the slotted lever, *h*; the stud, *c*, following the dotted line, *d d d*, transferring its motion to the valve through the short arm *i*, rod, *e*, rocker-shaft, *f*, and valve stem, *g*, the point *i* traversing the small dotted circle. As the main rod in passing the centres travelled slowest, the movement of the valve was also slowest at that point, when it should have been the quickest. Mr. Melling obviated this, however, by operating the right-hand valve from the left-hand main rod, and *vice versa*, which change greatly improved the action. From this gear (of 1830) has grown several others of more or less similarity, the most prominent of which, at present, is Joy's.

Fig. 8 is Hawthorn's gear of 1838. Like the preceding, this also takes its motion from the main rod, and, of course, dispenses with eccentrics. The amount of lead is dependent on the inclination of the slotted piece, *a*. In reversing the engine, the tumbling-shaft, *c*, was operated by the reach-

rod, *d*. Two arms, *i* and *j*, by means of the hangers, *f* and *k*, changed the inclination of the piece *a*, and simultaneously ungeared the bottom hook from the stud, *m*, and threw the upper hook into gear with the stud *n*, the rocker arm, *o*, swung on the shaft, *l*, and received its motion from the arm, *p*, which was attached to the upper arm of the slotted piece at *r*. The pin, *g*, followed the dotted line, *h h*, *b* being the valve-stem. As the motion was in no way superior to that of an eccentric, and the whole was somewhat complicated, it died a natural death.

Up to this time (1838), the slide valve in use on locomotives had little or no outside or inside lap, and consequently took steam on one end at the same time the exhaust opened on the opposite end of the cylinder. No attempt at using steam expansively had been made up to this year, when it was found that engines having considerable outside lead, and consequently with this valve the same amount of inside lead, thus allowing of an earlier opening of the exhaust, were burning less fuel and were smarter. The good effect of an early exhaust being clearly demonstrated, it was but a step to add outside lap, which was tried on the "Lightning" of the Liverpool and Manchester Railroad. This engine's valves were changed to $\frac{3}{8}$ outside lap, and set with little or no outside lead. The effect of this was to reduce the fuel consumption 25 per cent. In 1840 engines were running with $\frac{3}{4}$ and 1 in. outside lap on English roads, and no expansion obtained save that due to the lap. The following table illustrates the importance of this addition of outside lap:—

Consumption of coke			
per mile, 49 lbs.	...	valve, $^1/_{16}$ in.	... outside lap, 1839.
,, 36 lbs.	...	,, $\frac{3}{8}$ in.	... ,, ,, ,,
,, 32 lbs.	...	,, $\frac{3}{4}$ in.	... ,, ,, ,,
,, 28 lbs.	...	,, 1 in.	... ,, ,, ,,

In 1839 Gray's variable expansion gear was applied to a locomotive, and to Gray is due the honour of having first made the application of the principle of varying the travel of the main valve to produce expansion on any kind of steam engine.

Fig. 9 shows Gray's gear; *b* is the crank, *g* and *h* the centres of the two eccentrics *e* and *f*. The ends of the eccentric rods are fitted with blocks which slide when in gear in the slotted lever, *L*, which is hung at *m*; *d* is the valve stem attached to the lever at *x*; *c* is the reach-rod which moves the frame, *W*, which is supported on stationary pins, *V V*, over which the frame, *W*, moves by virtue of the slots, *U U*. In reversing the engine in the gear shown, the frame, *W*, is moved to the right, which movement, by means of the pins, *y* and *q*, attached to the frame sliding in the slotted levers, *t* and *p*, hung at *S*, lever *o* being part of and fastened to *t*, the lever *n* being part of and fastened to *p*, depresses the lever or arm, *o*, and raises the lever, *n*. This movement through the links, *k* and *j*, which are attached to the end of the eccentric rods, lifts out of the curved slot in the lever, *L*, the rod, *f*, and pin or block, *i*, and throws into this slot the block, *e*, on the end of eccentric rod, *e*. The change in the travel of the valve and consequent expansion is produced by raising or lowering the pins, *i* and *e*, in the slot when either were in gear. The lever, *L*, being struck to the radius of the eccentric rods, the lead remains unchanged.

It will be noticed that as the frame, *W*, is moved to the right, the pin, *y*, produces no movement of the lever, *t*, and arm, *o*, until the pin reaches that portion of the slot in *t*, where it dips downward, while the lever, *p*, is at once lifted. The condition is evidently necessary, as, if the eccentric-rod, *e*, commenced to lower simultaneously with the raising of the rod, *f*, the result would be the locking of both pins or blocks, *i* and *e*, in the slotted lever, *L*. It is also evident that as the pin or block, *i*, is raised on the slot of *L*, that the travel of the valve stem, *d*, is shortened, and hence expansion occurs. This invention of Gray's was a very important step in the right direction, as the principles involved are those which underlie the link motion as used to-day.

Fig. 10 is another application of varied travel to obtain expansion, which appeared soon after Gray's. *C* is a rocker-arm having a slotted and forked addition to its lower arm; *i* is the go-ahead eccentric rod fitted with a pin, *h*, which is raised or lowered in the slot, or lowered entirely clear of the slot and fork by means of the tumbling-shaft, *b b*, and hanger, *k*; *d* is the valve stem. It is evident that by lowering the pin, *h*, in the slot, the travel of the valve will be shortened, and *vice versa*, and hence expansion occurs. In reversing the engine, the pin, *h*, is thrown clear of the lower forked end of the rocker-shaft, which movement through rod, *e*, rocker-arm, *f*, and hanger, *g*, lifts into gear the lower hook, *j*.

The first link motion is that shown in Fig. 11. The slotted link, *a*, is fastened to one eccentric strap at its top end at *c*, and to the other at its bottom end at *d*, The reversing of the engine consisted of shifting the block, *b*, to the opposite end of the slot, which also carried the rod, *e*, attached to the valve stem, *f*, with it, *g* being the tumbling shaft. In 1843 a Mr. Howe produced the link motion, shown in Fig. 12, which requires no explanation, as it is essentially the link motion of the present day. Stephenson first applied this to the locomotive.

Fig. 13 is an independent cut-off gear, which a few years since was much used in the United States. This gear, when correctly designed, makes a much smarter and more effective engine than the ordinary link engine, as has been repeatedly demonstrated in practice.

It is essentially the gear, and involves the principles so extensively used in marine and stationary work where economy and effectiveness are necessary. It consists of a main valve, *c*, and a cut-off valve, *b*. The main valve is operated by a rocker-arm and reversed by hooks, *i* and *j*; *a* is sword-arm rocker-shaft, receiving motion from an eccen-

tric rod, *k*. Expansion is effected by altering the travel of the valve, *b*, by raising the block, *x*, on the sword-arm by means of the shaft, *f f*. The cut-off rocker-arm and main valve rocker-arm are concentric, one being a sleeve working around the body of the other.

Fig. 14 shows the Walschaert gear, which dispenses with eccentrics, and has a limited application in the United States ; *a* is the valve-stem, *b* a lever, which receives motion at its lower end by a link, *p*, operated by an arm, *o*, bolted to the cross-head, *q* ; *n* and *n* being the guides ; *f* is a slotted link hung at *g*, which receives motion through a rod, *h*, attached to a return crank, *l*, from the crank pin, *j* ; *m* is a tumbling-shaft, by means of which the block, *d*, is shifted to any intermediate position, or to the other extremity of the link, *f*. It gives results equal to the ordinary stationary link.

Fig. 15 is the Allen straight link, used extensively in England. In reversing the engine, the link and valve-stem are moved in opposite directions simultaneously, as one end of the tumbling-shaft arms is connected to the link and the other to the valve stem. It is claimed that this link gives superior results to that of the shifting link used in the United States, and that in well designed Allen links the lead is unchanged.

The Joy gear, which is receiving some attention in this country, is an English invention, and is shown in Fig. 16. A rod, *s*, fixed stationary by a pin at *i*, but which is free to turn on this pin, is attached to a rod, *f*, at *j*. The top end of the rod is attached by a pin to the main rod, *h*. Another rod, *e*, is coupled to the rod, *f*, at *k*. The upper end of the rod, *e*, is coupled to the valve stem, *a*, at *d*, and just below this point a second connection is made to a block, at *l*, sliding in a short curved piece, *c*. The inclination of the block, *c*, determines the travel of the valve ; *b* is the lever attached to the block, *c*, which is operated by a reach-rod, etc.

This gear is claimed to be superior to the link motion on account of its simplicity, and it certainly gives a better distribution of the steam than the link motion, as will be seen by the cards A, B, C ; and it would doubtless have as much wider application if it were not patented.

This gear will receive a closer analysis and description hereafter, as its merits, as compared with the link, make it worthy of attention.

LIGHT RAILWAYS.

BELPAIRE'S STEAM CARRIAGE.

SLIDE MOTION.—As intimated in our last issue we now give a fuller illustration and account of the Walschaert Gear, as applied to Belpaire's Steam Carriage, then shown on Plate CXLII. Through a regretable oversight, mention was unfortunately omitted that for what has appeared on the subject of Light Railways in our February and March numbers, we were indebted to the *Revue Générale des Chemins de Fer.* On Plate CXLV. of this present number it is shown again, enlarged and with cranks turned half a revolution. The engine is also reversed, the dotted work representing reversing gear in forward position, as shown in full on Plate CXLII.

In common with some other gears, the reciprocation of the valve is here the resultant of two other motions imparted to it. These two at times acting together ; or one acting alone, with the other comparatively still ; or counteracting each other.

In the Walschaert Gear, the two original motions are derived one from the main crank and the other from a second crank at right angles to it. In single cylinder engines, or in locomotives with outside cylinders, these secondary cranks are generally overhung cranks. But in this present arrangement, with the cylinders inside, the proximity of the two cranks is turned to account by making each the secondary crank to the other.

In the illustration, B B′, (Plate CXLV.), are the cross-heads, with two arms projecting sideways and upwards from each, $A_{,}$, A′, A, $A_{,}'$, best shown in Fig. 2 From the two outside arms, $A_{,}$, $A_{,}'$, run two rods forward to *d* and *d*′, where they join the upper ends of vibrating levers, *g*, *g*′, connected to the slide-valve rods at *h*, *h*′. From the two inner arms, A and A′, two rods, *i* and *i*′, run backwards to *b*′ and *b*, where they are connected to the upper ends of vibrating levers, *l*′ and *l* respectively, These levers actuate separate rocking shafts, *r* and *r*′, at the outer ends of which are oscillating links, *c* and *c*′. The left-hand cross-head thus actuating the right-hand link, and *vice versa.* From these links the connecting rods, *s*, *s*′, run forward, and are fixed near the lower ends of vibrating levers, *g*, *g*′. Q is the reversing lever, actuating rocking shaft, *o*, at the outer ends of which are cranks, from which drop arms, *m* and *m*′, to the connecting rods, *s* and *s*′, respectively. The action is as follows :—Taking the cranks in position, as shown on

Plate CXLV., they are revolving in direction indicated by the arrow. The leading crank C′, as regards any reciprocating motion backwards or forwards, is at full speed, while crank *C* is comparatively at rest. Consequently cross-head B′ is also at full speed, and B at rest. To consider the effect on one slide valve at a time, that at *t*,—through B being stationary, *d* is also at rest. But B′ moving rapidly, the lever *l*, by means of rod *i*′, is being sent backwards, so that connecting-rod *s* is also made to move in the same direction. The rod *s* being connected at *f* to lever *g*, the upper end of which is at the moment stationary, imparts its motion to the slide valve, opening the steam port further than it was already. During the revolution through the next 45 deg., both cranks are moving in the same horizontal direction, so that B now moves in the same direction, and at the end of that time, with the same speed as B′. Consequently the upper end of the lever, *g*, is now moved with the lower end, the speed of the valve having thereby become much accelerated, and the steam port nearly wide open. At 90 deg. B′ is stationary, though B is moving rapidly; so the slide valve is still in motion, but with diminishing speed. At the end of 135 deg. B′ is moving in the contrary direction to B, so they neutralize each other, and the valve remains stationary wide open. During the last 45 deg. the motion of B′ has gained complete ascendancy over that of B, and is causing the slide to fly back, securing a quick "cut off" and opening the other steam port, the amount necessary for "lead," by the time B is at the end of its stroke.

If the reversing lever, Q, were put into forward position, *C* would then become the leading crank. And although the cranks would revolve in contrary directions, yet the slide at *t* would move exactly the same as already described. B would go forward obviously as before, so sending *d* and *g* in same direction, and *s* will still derive its previous motion from B′, through being now connected to lower end of oscillating link *c*, instead of upper end.

RAILWAY SIGNALLING.

INTERLOCKING POINTS AND SIGNALS.

(*Continued from page* 78.)

HAVING in our last number placed before our readers a brief history as to the origination of the "Interlocking System," we shall now proceed to consider some of its early developments.

As already mentioned, at an ordinary double junction, it is usual to have an up and down, main and branch, home and distant signal lever, besides two point levers (with sometimes a corresponding number of levers for the locking apparatus where facing points are employed), in which cases there would be a complement of from nine to twelve levers in the frame.

The points and locking apparatus are usually attached to their levers by gas tubing of about an inch in diameter, connected in convenient lengths by screw sockets, and provided at suitable intermediate positions with auxiliary adjusting and compensating devices as previously explained.

Compensators are usually employed in all cases where the rods are over 150 to 200 yards long, but some engineers prefer to apply them at much less distances. Trailing points are similarly connected up to a distance of 350 or even 400 yards, but facing points are limited to connections of 150 yards, as previously mentioned in some early numbers. Signals are connected to their levers up to a distance of about 1,500 yards, but beyond 900 yards the working becomes troublesome.

Three years after the important invention of Mr. John Saxby, described in our last number (*i.e.* in 1859), Mr. Austin Chambers introduced an invention, being in reality a development of Mr. Gregory's frame of 1843, that is the locking was extended on a similar plan to control the points as well as the signals.

This advancement of Mr. Chambers was destined to occupy a very important position in the history of interlocking; indeed, some versed in these matters have gone so far as to speak of this invention of 1859 as being really the original foundation of the "system," but this we are hardly inclined to accede to.

Before describing this improved construction of interlocking frame, we will briefly consider some of the circumstances under which the invention was ushered into the arena of railway enterprise.

When the Hampstead junction line was completed in the latter part of 1859, Colonel Yolland (Government Inspector of railways) expressed an opinion that he did not consider the signalling arrangements of Kentish Town station at all satisfactory, and that some means ought to be devised to prevent the operation of points and signals at random. Messrs. Stevens & Sons being the appointed signal engineers, they undertook to arrange the signals in accordance with the Government Inspector's views, and therefore the opening of the line was delayed for this purpose. When the arrange-

ments were completed Colonel Yolland again attended for inspection. The interlocking frame devised was really of similar construction to that of Mr. Gregory's, *i e*, foot stirrups were provided for working the signals, and were so disposed with suitable connections that upon one stirrup being forced down another or others were liberated. However, Colonel Yolland happened to try the behaviour of two stirrups when acted upon simultaneously, and in this manner discovered that two conflicting signals could be operated upon at the same time, whereupon he refused to allow the opening of the line. When asked how the conditions could be altered and the difficulties overcome, the Colonel briefly replied, "It is not within my province to suggest but to approve!" Mr. Chambers (then engineer to the line) began to carefully think over the matter himself, and having established certain requirements essential for working traffic with safety at such a junction, he successfully hit upon a solution of the problem. About a month later Mr. Chambers succeeded in designing a frame which was erected by Messrs. Stevens & Sons, at Kentish Town and Willesden junctions, at the latter part of December of 1859, and which met with Colonel Yolland's entire satisfaction.

It may be interesting to our readers to quote here the concluding remark of the Colonel to the Manager of the line, upon making this final inspection: "You see I have not asked for more than could be done, as one of your own staff has provided it; you will some day thank me." There can be little doubt that not much time elapsed before they thoroughly appreciated the keen perception and judgment of Colonel Yolland, and since that date we have all had occasion to recognize this gentleman's efficient and strenuous discharge of his official duties, and we regret that there is not at present more of such consistent dictation as to what Railway Companies ought to do and adopt. Improvements are at present left too much to the convenience of Railway Companies, who frequently avoid small expenditures, heedless of the public safety, but which generally proves an expensive policy in the long run.

But to return to Mr. Chambers' invention. This gentleman's perseverance and ingenuity resulted in a successful issue, and we are indebted to him for a substantial step in the history of interlocking. The same day that the Government Inspector had passed the line, the General Manager sent Mr. Chambers a cheque to have his invention secured by Letters Patent. Some few weeks after the procuration of his patent, the invention was offered to Messrs. Stevens & Sons for £100, but the offer for some reason was rejected. And in conclusion, it may be worthy of remark, that Mr. Chambers' frames were worked with satisfaction for years, and some of which were still in use a very few years back, and had never required substantial repairs.

We must now ask our readers' brief attention to the construction of the frame itself, part of which is shown in tranvserse section at Fig. 195 of the drawings, Plate CXLVI, and it will be understood that any convenient number of such elements or parts may be combined together and would be correspondingly seen in front elevation.

Let A represent a lever controlling the "up," and *B* similarly the "down points," the former being open to the "main" and the latter to the "branch line." The signals are worked by chains passing over pulleys suitably arranged, and connected to the stirrup rods, *d*, which are provided at their lower extremities with prolonged pieces in the form of bars and rods. The point levers are connected to longitudinally sliding plates, *c*, having holes or perforations therein, and which receive a corresponding reciprocating motion with the angular movement of the said levers. Now, according to this arrangement, it will be readily seen that unless the point levers have been previously properly moved to prepare the road the signals cannot be given, because the movement of the projecting pieces on the stirrup rods are mechanically obstructed by the position of the sliding plates, *c*. But when such previous operation has been properly effected, the perforated portions of the said sliding plates are then brought under the vertical projections on the stirrup rods, so that the signals may be lowered. In this manner, by providing all the point levers with perforated sliding plates, the operation of the signal stirrup rods were completely controlled, so that the action of the latter were rendered dependent upon the former.

According to a modified arrangement, Mr. Chambers also provided levers for the actuation of the signals, and attached to them at suitable intermediate positions curved bars or rods (analogous to Steven's present frame), which similarly acted upon and were controlled by sliding plates, operated by the point levers. But this last arrangement, however, was not always so effectual, as under certain circumstance, in which a large number of points were desired to be controlled, a considerable movement of the signal gear was permitted before the locking action was effected.

As, later on, the general construction of the point or signal levers with their appendages have, more or less, some connection with certain systems of interlocking, we have illustrated a side elevation of such a lever at Fig. 196. Let A represent a point or signal lever, which is usually in the form of an ordinary bent lever of the first order, pivotted on a fulcrum pin at B, carried by a suitable bearing C, conveniently fixed on a girder or part of the framing of the apparatus. To the short end, *a*, of the lever is connected the wire signal pull or point rod connection, according to the office it is required to perform, while the upper part thereof is arranged to work within segmental plates or checks, D, fixed to the floor or foundation, and provided upon its upper surface at suitable positions with notches, d d^1. Into these notches fits a bolting-piece, *e*, formed at the end of the spring catch-rod, E, which is free

to move up and down vertically when the operator grasps the lever, and likewise pressed the hand-piece, F, so as to raise it against the action of the helical spring, *f*. When the handle is released, the bolting-piece, *e*, is forced into the notches (i.e. when the lever is moved over it) by means of the recoil of the before-mentioned helical spring, *f*.

It is desirable to devote these few lines to the construction and arrangement of the lever and "spring catch-rod device," although, it may appear a very elementary and well-known piece of mechanism, because we shall hereafter have occasion to more particularly refer to it as performing an important part in the more recent systems of interlocking.

As we must now pass on to consider a different type or principle of locking altogether, and in which the locking of the levers is effected by sliding bars having an intermittent reciprocating motion, we may, therefore, advantageously pause to examine a simple diagram represented at Fig. 197 of the drawings, which will serve as an elementary introduction.

Let A represent a lever for actuating a pair of points, and B and C levers working signals concerned therewith, and all of which are mounted on fulcra G, G^1, G^2. D and E are parallel sliding bars or plates, situated one above the other, and capable of receiving longitudinal reciprocating motion by any convenient bed-crank connections, when the last-mentioned levers are pulled forward.

These sliding bars or plates are provided with vertical rectangular slits, notches, or recesses, *d* and *e*, respectively, in which a bar, F, attached to the point lever, is, under certain conditions, allowed to work in a vertical plane. This bar is also provided with similar notches, $f f^1$, arranged longitudinally and at right angles to those in the sliding plates.

Now, assume the condition of this primitive device to be so arranged that, when the signal levers (which, for example, may be any concerned) are in their normal position, both the notches, *d* and *e*, formed in the sliding plates, D and E, are exactly over each other and opposite to the notched point lever, F, and in which position the point lever is free to be moved by virtue of the bar, F, being free to move up and down vertically in the coinciding notches, *d* and *e*.

But now assume any other of the levers to be previously moved—say, for example, B, into the dotted position *b*—then the sliding plate, D, would be caused to make a lateral movement to the right by passing through the transverse notch, *f*, in the point bar, F, thereby bringing the notch, *d*, into the dotted position, d^1. In this manner a solid part of the sliding plate, D, is brought to engage with the point bar, F, so as to lock it and render it inoperative during any such position of a certain signal.

In a similar manner the movement of the lever, C, and plate, E, would be capable of controlling the point lever, A. In this way any number of signal levers might be arranged to control the action of a point lever, which would only be free when all levers concerned were returned to their normal position, and, therefore, all the notches in the sliding plates moved to occupy exactly the same vertical plane.

It will be further understood that, if desired, such an elementary contrivance could be extended to similarly control the operation of the signal levers, in order to prevent the actuation of conflicting signals, in which case it would only be a matter of working out detail arrangements as to what levers were to be held secure when others were free.

We have previously called attention that Mr. Saxby very soon found his original frame, as designed in 1856, to be somewhat cumbersome and not generally suitable, and consequently he variously altered and improved this apparatus (*e.g.* 1858) until we find him in 1860 employing horizontal rocking or vibrating levers or bars, having stops, studs, or angular projections thereon, and arranged to work in front of the point and signal levers which they are caused to control.

These bars or levers were caused to move laterally by the levers working against their inclined sides or edges, so that certain projections were caused to engage with certain conflicting levers, which were desired to be secured at certain intervals. We shall not give an extensive illustration or lengthy description of this improvement, as it is of no particular consequence to us at the present time, further than worthy of notice as a step of advancement and the early adaptation of horizontal sliding or vibrating locking bars.

In fact, from the elementary diagram previously given, it will be now more easily understood how projections, moving in front of the vertical hand levers, in lieu of notches, could be caused to lock all those not required to be free, and similarly liberate those desired to be moved.

At Fig. 198 are represented diagrammatic plans of portions of such locking gear of 1860, which will suffice to give our readers sufficient notice of the principle involved.

In practice there would be three or more of such sets or arrangements of vibrating locks, placed one above the other in horizontal parallel planes.

When all the signals are "on" or at "danger," the point levers should be capable of being actuated at pleasure, and which is the case with the point lever represented in section at A. The branch signal lever, C, will, however, under the same circumstances be seen to be secured by the angular projection upon the vibrating lock, F, whilst the main line signal lever, B, is free to be moved as shown, and which is required to be actuated independently of the point lever, A. Therefore, while the last-named lever occupies its front or normal position in the frame, the main line signal is capable of being "lowered." The locks consist of irregular pieces of metal, D, E, and F, i, I, and J, j, presenting inclined sides or edges, and which have fixed

fulcra at *g*, on the framing, G, while their opposite ends are pivotted at *h* to the sliding bars, H, H^1, and H^2, capable of alternate reciprocating motion within suitable guides, as the levers are moved against the aforesaid inclined faces of the locks.

Now, assume the free lever, B, to be pulled over to lower the main line signal, the lock, I, similarly arranged below in a lower horizontal parallel plane, would be forced over by the movement of the lever in the direction of the arrow, so as to bring a projecting shoulder behind the point lever, A, thus holding it securely in place during the "clear" signal for the "main line," the branch signal lever, C, being normally locked, as shown and hereinafter explained.

Upon returning the main line signal lever, B, to its normal position it acts against the piece, i, and so moves the sliding bar, H, and locks to the left so as to free the point lever again.

Now, conversely, assume it is desired to give the signal for the "branch line," which is incapable of being performed until the main line signal is put "on," and the point lever moved so as to free the lever, C. This is effected as the lever, A, is pulled back to set the points right for the branch line, which acts against the inclined side of the pieces, D, and thus forces the sliding bar, H, to the right, so as to lock B and liberate C. The latter lever is now free to be moved over, so as to give the "branch" signal, and by which operation the locking of the point lever in its back position is effected.

For this purpose another sliding bar, H^2, is provided below that of H^1, working similar locks and pieces, J,j, so that as C is pulled back it acts again the pieces, j, and thus locks the point lever, A. After the branch signal lever is returned, the lock, J, is removed from the point lever, when it can likewise be pushed back to its normal attitude.

In this manner the points and signals are only permitted to be operated in harmonious or concurrent sequence, and it will be readily understood that the "system" may be extended to meet any requirements of traffic and the number of levers to be controlled.

About this date Messrs. Stevens & Sons brought out a frame on a somewhat similar principle to the above, and in which locks or claws were arranged on horizontal sliding bars, and so caused to move as to engage with certain levers. The sliding bars carrying the locks were caused to move in one direction by the movement of the levers, and afterwards returned to their normal position by means of helical springs. Auxiliary locks were further provided for "back locking" the levers.

Another modified arrangement of interlocking gear is shown at Fig. 199, and the invention of Mr. Michael Lane in 1865.

The necessary motion to be derived from the levers was communicated to the locking connections, C, through the intervention of the rack and pinion motion, A and B. The pinion was fixed on a spindle terminating with a screw, which worked nuts so as to control the locking mechanism, D.

This apparatus, however, never achieved much popularity or was much used.

We will now pass on to examine, with reference to Figs 200 and 201, the interlocking apparatus of Messrs McKenzie, Clunes and Holland, of the Vulcan Ironworks, Worcester, and which was invented by these gentlemen in 1866.

A, in the respective views represents a lock controlling an "up main" signal lever, actuated by the "up-point" lever through the intervention of the rocking or vibrating lever, B, and bar C. D is the "branch distant signal" lock counterpoised at *d*, and acted upon by the up and down point-levers, through similar levers and bars B and B^1, and C and C^1 respectively. The small rectangular sections, 1 to 4 and 7 to 9, represent the signal levers fulfilling certain offices which are written against them in the drawing, while the Nos. 5 and 6 indicate the point levers. S is a shaft or spindle common to all these levers, and by which they are carried, while L is a separate counter shaft or spindle, carrying the said locks and vibrating levers. The signal levers are provided with studs or projections, H, for actuating the aforesaid locks, while *h* h^1, are provided upon the point levers for a similar object. The locking connections are more clearly shown in the horizontal section taken through the frame, in which the main-line locks, A A A, are represented as being out of operation, while those of the branch, D D^I D^{II}, are conversely indicated as being "on."

We shall not give a lengthy description of this apparatus, as the drawings will sufficiently explain the general features and operation thereof, and later on we shall have occasion to more extensively consider the same type of frame in an improved form, and as at present used on many of our railways.

In 1867 (the following year), Mr. Saxby made some improvements upon that type of apparatus invented by him in 1860, and which we have already explained. In fact, during this year, Mr. Saxby contrived numerous novel arrangements and modifications, displaying much mechanical ingenuity and for which he procured several new patents, in connection with which some matters of peculiar interest arose, and which we shall later on briefly refer to.

In the month of February of this year, Mr. Saxby filed a specification of a voluminous nature, incorporating more than one interesting arrangement of interlocking apparatus.

The first of them that we shall now refer to is illustrated at Figs. 202 to 205. Plate CXLVII of the drawings, which relates to the use of horizontal circular locking plates, C,C^1, for the purpose of economising space. One of these plates is attached to the end of the vertical spindle, B, whilst the other is similarly connected to the hollow or

tubular shaft, B^1, and which are actuated by the point levers, *h*, and *c*, respectively.

These point levers are arranged so as to be capable of receiving angular motion in a horizontal plane, and are suitably connected with the aforesaid solid and hollow shafts as shown.

The circular locking plate is provided with curved slots, *s*, corresponding to others arranged in a similar stop plate.

The signal levers are provided with vertical rods, D, E, &c., working or performing similar functions to the ordinary horizontal apparatus, but in combination with the point levers, *c*, *h*, as represented, which work the circular plates, C, and C^1, before referred to.

In the same specification an elaborate description is given with regard to some improvements in the ordinary horizontal apparatus, and which are illustrated at Figs. 206 to 210, which represents the application of such an arrangement of frame to controlling the traffic of an ordinary junction involving the use of 9 levers.

The functions of the levers, and the order of working, as also their controlling action, will be understood by the following tabulation :—

Lever 1 actuates the distant signal of the up branch line III (see plan of roads Fig. 206).
Lever 2 actuates the distant signal of up main line 1.
Lever 3 actuates the points of up main and branch lines I and III.
Lever 4 actuates the junction signal of up branch line III.
Lever 5 actuates the junction signal of down main line II.
Lever 6 actuates the junction signal of up main line I.
Lever 7 actuates the junction signal of down branch line IV.
Lever 8 actuates the points of down lines II and IV.
Lever 9 actuates the distant signals of these lines.

For effecting the necessary interlocking action three slides, A^1, A^2, A^3, are arranged in the frame, one above the other in horizontal parallel planes, and which carry vibrating locks, B, acting substantially similar to the arrangement of 1860, already described, the only difference being a modified method of imparting motion to them.

These locks have fixed fulcra at *g*, and while their other ends are free to reciprocate with the aforesaid sliding bars. In the vertical sectional elevation, L and M represent the two point levers, the former being "closed," and the latter in its "open" position.

As the lever, L, is moved upon its fulcrum, the forked rod, *a*, in connection therewith is also set in motion which works the crank, *b*, one arm of which is attached to *a*, while the other engages against the concave or recessed face of the lever arm, *c*, which thus causes the latter to rock on the centre, *d*. The opposite end of the lever, *c*, engages with a stud or pin, *e*, on the sliding bar, A, to which it imparts an alternate lateral reciprocating motion, so as to move the required locks, B, over certain levers by means of their free connection at f, and fixed fulcra at *g*, respectively.

The inclined edges to the locks, B, simply facilitate the action of the other portions of the apparatus when the hand levers are moved against them.

The various repeated letters in the drawings, bearing the consecutive numbers up to nine, simply relate to corresponding parts, having the same construction and similar functions to fulfil, and, therefore, really only differing with regard to position.

The general operation of the apparatus and special duty of each lever will be seen below :—

By pulling over lever No. 1, No. 3 is locked open and 8 secured, normal or closed.
By pulling over lever No. 2, No. 3 is locked in normal position.
By pulling over lever No. 3, Nos. 2, 5, and 6 are locked normal, 1 and 4 liberated.
By pulling over lever No. 4, No. 3 is locked open, 8 normal position.
By pulling over lever No. 5, No. 3 is locked normal.
By pulling over lever No. 6, No. 3 is locked normal, 8 open.
By pulling over lever No. 7, No. 8 is locked normal.
By pulling over lever No. 8, Nos. 1, 4, and 7 are locked normal and 6 freed.

The signal lever 9 is not connected or concerned with operation of the points, and is, therefore, omitted from the above table.

Fig. 211 shows one of many modified arrangements of Mr. Saxby's locking gear of 1867.

In this case the locks, B, are in connection with the hand levers, L, and slides, A, as shown. For the levers a series of transverse guiding plates are used, the back ends of which are connected by means of forked pieces with the said levers, while the front parts are fitted to slide into annular recesses formed in the slides, A, or between suitably arranged bosses provided on each side of the guide plates.

Now, if the levers are put into motion perpendicular or at right angles to the slide bars, A, the slides of the guide plates, *d*, bear upon the sides of the grooves so as to force them laterally in either direction. To prevent the plates, *d*, from deviating from their proper course of travel they are provided with perpendicular slots, *e*, in which guiding or stop pins, *m*, are fitted.

This type of locking gear was, however, soon found inefficient to meet the practical requirements for satisfactory work, for the locking apparatus was situated so far down the levers, and in consequence of such "draught or leverage" the "moment of force" thereby obtained was highly injurious to its durability, while the wear and tear

resulting therefrom necessarily rendered its action in time unreliable.

Mr. Saxby was not tardy in recognising these practical impediments to successful working, and immediately set himself about to devise a locking apparatus of a totally different character, and on the 26th of March of the same year he lodged a provisional specification for such improvements. Three days later, however, Mr. W. Easterbrook (late of Messrs. Saxby and Farmer's) likewise applied for the protection of an invention of an exactly similar nature, the bases of both these gentlemen's specifications being the *locking of the spring-catch rods* in lieu of the levers themselves, in order to overcome the difficulties above specified. No amicable settlement being apparently compatible under peculiar circumstances, legal proceedings resulted, in which, unfortunately, Mr. Saxby had an unsuccessful termination, and therefore Mr. Easterbrook was allowed the prerogative of the Crown. This apparatus we illustrate at Figs. 212 and 213 of the drawings, Plate CXLVI., and will be referred to in detail a little later on.

In consequence of the above stated complication, Mr. Saxby abandoned his application at the provisional stage, but his extraordinary mechanical versatility was not exhausted, and there yet remained a further requirement to be accomplished, and accordingly we learn of him, on the 20th of July in the same year, applying for another provisional protection. But most strange to relate, within three days after, Mr. Easterbrook again similarly applied for protection for exactly the same invention. Again legal difficulties ensued, but this time the latter gentleman came off worse.

The issue was necessarily of a most unsatisfactory character from every point of view, and especially for the public, as the two last-mentioned patents, i.e., the first granted to Mr. Easterbrook and the second to Mr. Saxby, were of such an intimate and inseparable character that the one could not be satifactorily worked without interfering with the rights of the other.

The subject matter of the first patent was, as before stated, for locking the spring-catch rods instead of the levers as hitherto, while that of the second was for *actuating the locking by the movement of the spring-catch rods.* Thus each was allowed his individual scope, while the public were debarred from the aggregate benefit, because these gentlemen could not manage to come to an amicable understanding.

It may be worthy of notice that, although Mr. Easterbrook's application was dated three days subsequent to that of Mr. Saxby's, he, however, managed to push the matter forward, so as to get his patent sealed prior to that of his opponent, which is generally to be considered the harbour of safety for competing inventors. However, this rule does not always apply, and, like many other unexpected complications of law, had in this case its exception, for it was subsequently held that the patents should take effect from their respective dates of application, and that, therefore, acts committed by virtue of the patent bearing the later date, would be held infringements upon the former or that of prior application.

This privilege has been allowed to inventors on more than one occasion, more especially in cases, for instance, where there has been some room for doubting the originality of a master or servants' invention, as then suspicions of a surreptitious nature become involved.

Inventors when drawn or enticed into such legal complications generally require the most skilled legal and scientific assistance if they desire to satisfactorily extricate themselves, and for this purpose so termed " Patent Agents " are commonly consulted, or have occasion to take part in some of the proceedings. We would not venture upon any unfair criticism of so obviously useful a body of men collectively considered, but we are afraid that individual analyses would result in rather unsatisfactory conclusions; for, indeed, very few of such gentlemen possess sufficient legal or scientific knowledge and experience, or are in any degree competent to fulfil the capacity to which they aspire. The resulting troubles amongst their clients by the extraordinary constructions which their specifications subsequently bear, the invalidity of claims and consequent legal difficulties, should be (to use a railway expression) "on or danger" signals to any intending patentees, to whom advertisements or cheap prices for professional services are unwise inducements.

Before closing these lines of experienced admonition, it is only just, on the other hand, to state that there are some few at the head of the profession of the most exceptional heterogeneous technical learning and legal experience, and amongst the foremost of these we cannot fail to recognize the services of such gentlemen as Messrs. Abel & Imray, and J. H. Johnson, whose keen ability and judgment most railway inventors have had ample opportunity to appreciate.

In consequence of the circumstances before mentioned, Mr. Easterbrook nas confined himself to his divided privilege, and which is still incorporated in his frames of the present day, while Mr. Saxby has similarly extended his developments within the precincts of his legal demarcation, and is still well-known under the distinguishing definition of his *catch-rod actuation.*

In Mr. Easterbrook's frame (see Figs. 212 and 213), Plate CXLVI, he increases the length of the spring-catch rods, and provides them with T terminations, with which hooked catches, mounted on rocking spindles, are caused to engage at the required intervals.

In this manner it is rendered impossible to move any of the main levers when the spring-catch rods are thus held down in the notches of the quadrants, and further, unless the levers are pulled or brought quite over, and the catch rods down in their respective notches, the signals are prevented from being lowered. Several series of horizontal bars may be applied to the same spring levers, either (or both) above and below, and the proper connections secured between the rocking shafts by rods and rocking links.

A, A^1, A^2, are the point and signal levers respectively pivotted at A^1. There are actually nine such levers, as shown in the front elevation, two for operating the points, and seven for the signals, the arrangement being suitable for the working of an ordinary junction. *a a* are the spring catch rods shown in their normal position, having pieces fitting into the notched quadrants a^1, and then extended down below the top plate or framing. These extensions are jointed at B, and are provided at their opposite ends with cross pieces. C, above which hooks or catches, D, (carried by the rocking shafts or spindles, E), are periodically caused to engage so as to hold down the spring-catch rods, and so prevent their stop pieces being withdrawn from the notches in the quadrants.

The rocking shafts are actuated by the *motion of the levers* mounted in convenient bearings as shown, and which operate the horizontal connecting rods, F, actuating the arms, G, connected with the aforesaid rocking shafts. The notches cut in the quadrants, a^1, for the reception of the pieces on the spring-catch rods, are represented at a^2 in the drawings, into which the said rods, *a*, are held down by the hooks or catches, D.

By constructing these extended spring-catch rods in two pieces, jointed at B, the upper portions may be disconnected for repair without disturbing the locking gear below.

The levers, numbered 5. 6, and 8, work the back, while 2, 3, 4, 7, and 9 the forward locking action respectively. In the transverse section all the levers are shown in their forward attitude, and consequently all the signals are at danger. By pulling the levers 1 and 4 over, the signals are lowered or taken off for the "up main line;" and 9 and 7 would similarly actuate the "down main" signals. In both these cases the branch line signal levers, 2, 3, 5, 6, and 8, are locked. No. 1 is, however, not required to be locked, as it works both the up main and branch distant signals. When the point levers, Nos. 2 and 3, are pulled over, 5, 8, and 6 are unlocked; but when the branch up signal (5) is pulled over, it back-locks the point lever (2).

When the branch down signals (8 and 6) are operated, the point lever (3) will be back-locked, while Nos. 4, 9, and 7 main up and down signal levers will be locked in their forward position. In this manner it will be understood that all liability of antagonistic working of the points and signals is prevented, and only a mutual and harmonious working rendered possible.

To prevent the hooks or catches, D, being strained, stops, *c*, are provided on the main levers, between which, and the cross pieces, C, the said hooks pass by the locking actuation. Thus, as long as the catch rods are locked down in their notches, the main levers cannot be moved, and by such arrangements of locking all excessive strain on the apparatus is prevented, as the leverage capable of being obtained by pressing the handles of the spring-catch rod is comparatively very small.

This type of frame is still considerably used on many of our railways, and are now manufactured by Messrs. Easterbrook and Hannaford, of Westminster.

The improvement upon this frame (in July), and the supposed simultaneous invention of Mr. Saxby and Easterbrook, we shall now only briefly allude to, because later on we shall have occasion to more minutely explain the "spring-catch rod actuation" as applied to some of the former gentleman's more recent frames. The general idea, however, was by employing a combination of notched plates, or equivalent devices and stops on the main levers, certain sliding bars were caused to be moved upon raising the spring-catch rod, so as to lock the catch rods of other conflicting levers.

In the same year Mr. Francis Brady, engineer of the South Eastern Railway, brought out a different form of frame, and which is illustrated in end view, at Fig. 214, of the drawings. Plate CXLVII, A and B are point levers of the main and branch lines, respectively, *d* and d^1 are horizontal rocking spindles, mounted in suitable bearings, and carrying the locks, D and D^1, which are connected by cranks to the rods, E and E^1, attached to the aforesaid levers A, and B.

To each of the original levers is connected a transverse horizontal bar, C, which is capable of receiving alternate reciprocating motion, upon the radius links, C^1, C^2, which have fixed fulcra at, *c*, c^1.

These transverse bars are always parallel to the base of the frame, while the links bear a similar relation to the signal levers, and against the latter, and consequently the levers, the locking pieces, C^1, C^2, are caused to act.

In the state of affairs represented in the drawing all the signals are supposed to be standing at "danger," and therefore the point levers are free to be moved, and which has been fulfilled with regard to A. This movement will be seen to have raised the lock, D^1, hard up against the face of the link, C^2, so that neither it nor its connections can be moved. While on the other hand the face of the lock, D, will be noticed to be clear of the link, C^1, which is consequently free to move, so as to allow the relative signal lever to be operated.

In this manner it will be readily understood that the locks, D, may be so suitably arranged upon the partially rotating horizontal spindles that they may be caused to rise and engage as required with the links of any conflicting levers.

Mr. Buck, of the Brighton Railway, in 1868, brought out an ingenious piece of apparatus, in which each lever was provided with locks of peculiar form and action.

During the normal position of the levers, the locks were arranged to fall clear or out of action by their own weight, but the number of sliding bars subsequently brought into action, and combined with general lack of simplicity, was against its general use.

Very shortly afterwards, Messrs. Livesey & Edwards followed with a frame of quite a different character. In their apparatus a short arm mounted on a fulcrum, and terminating with eye piece, was provided above each lever. When a lever

was moved, one of these arms was caused to bring its eye piece in connection with the conflicting signal lever so as to lock it. This arrangement, however, had the disadvantage of requiring additional gear for the back-locking action.

At Fig. 215 is shown a novel device, proposed by Mr. R. C. Rapier, in 1869, for effecting the locking of conflicting levers, without the employment of any moving bolts, bars, links, or locks. This was achieved, to a certain extent, in a very simple manner, as will be readily appreciated upon reference to the drawing, while all the gear was in sight of the operator, which is always an advantage. For this purpose a bar was fixed upon the point lever handles, so as to extend across the signal levers, dividing them into certain series or sets, according to the functions they were required to perform, and the nature of the locking to be effected, the bars in each set being arranged at different heights according to requirements.

We have now laid before our readers the most important features and apparatus concerned in the early history of the "interlocking system," and in our next number we shall be in a position to consider the more modern appliances and those at present in use.

Of course, in treating such a voluminous subject as that now before us, we cannot pretend to notice all the various inventions of minor importance, although, individually considered, many may exhibit ingenuity of special interest. Amongst such inventors worthy of mention are Messrs. Deakin, Anderson, Bell, Brown, L'Anson & Kitching, Cashin, and Whiteworth, &c.

(*To be continued*).

THE TELEPHONE FROM 1837 TO 1882.*

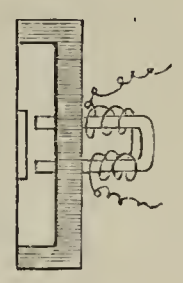
By AMOS EMERSON DOLBEAR, Professor of Physics, Tufts College, Boston, U.S.A.

WE publish the following report of a most remarkable lecture recently delivered by Professor Dolbear. The new facts for the first time submitted to the notice of electricians and scientists in this country will command the attention they justly merit. Professor Dolbear has kindly offered to exhibit and explain his discoveries to those who may desire further information, at the Offices of the London and Globe Telephone Company, 31, Queen Victoria Street.

The meeting was formally opened by the Chairman announcing Professor Dolbear, "of whom they had heard so much, and from whom they were now to have a lecture on the development of a new telephone system."

The Professor said that in the attempt he was about to make to show them something concerning the development of a new system of telephonic communication, he had thought it best, at the outset, to go hastily over the history of electric telephony. Of course, he knew that the main points in these matters were familiar, more or less, to them all, but he thought, if he devoted a little time to it, it would be refreshing the memory of some of them. Amongst the earliest attempts which had been made to transmit sound through the agency of electricity, the first that he knew of was that made by Dr. Page, of Salem, Massachusetts, somewhere about the year 1837. Those present would remember his device; it consisted of a bar of iron, around which was wound a coil of wire. When a current was passed through this, it gave out a sound; indeed, it gave out a sound every time it was magnetized or demagnetized. The bars were of considerable magnitude, some of them two or three feet in length. The cause of that sound was understood to be molecular disturbance whereby the bar was lengthened. When these sounds or clicks followed each other with a sufficient rapidity per second, of course, we have a continuous sound. The break-piece he employed was an automatic one—an electro-magnet and contact breaker. The sound he got was sufficiently loud to be heard at a considerable distance. He was not aware that Dr. Page made any attempt to transmit articulate speech. Of course, nothing but a certain definite pitch could be transmitted in that way.

The next attempt was by one they had probably not heard about—it was made by a Mr. Farrar, of Southern New Hampshire. He first proposed to make a kind of electric telephone in which sounds of different pitch should be transmitted. He, for his device, employed an electro magnet with a vibrating armature, something like this diagram. For his transmitter he employed a device consisting of vibrating reeds which could be manipulated by the ordinary keys of a melodeon or piano, opening and closing the circuit like Helmholtz's tuning forks, or like some of the devices employed in quadruplex telegraphy. With this apparatus he was enabled to transmit tunes. After that it occurred to him that it might be possible to transmit speech. He spent some time in experimenting, but did not succeed in making a transmitter. Soon after this, Helmholtz employed vibrating tuning forks with electro magnets.



About the year 1860, Philip Reis, of Germany, of whom they had heard so much, undertook, by himself

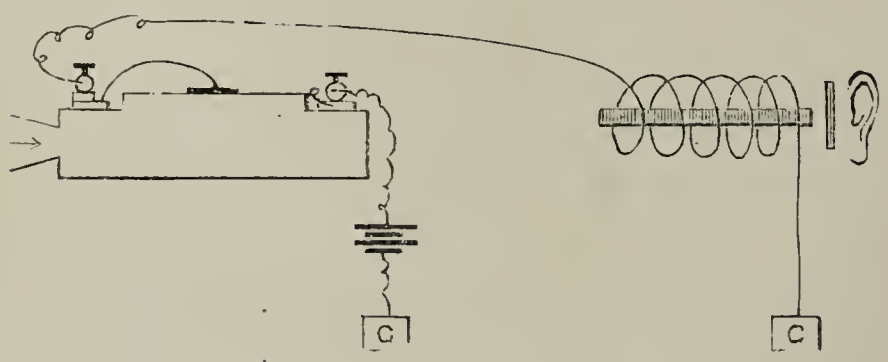
* A paper read before the Society of Telegraph Engineers, March 23rd, 1882.

and with extremely meagre resources to solve the problem of transmitting articulate speech. Let them suppose that this problem were to come to them to-day for the first time, they having possession solely of such knowledge of electricity and of the conservation of energy as existed in those days. It was known that a sound of a definite pitch could be reproduced at a distant place. The problem was how to make the vibrations of the human voice bring about the varying conditions in a current of electricity which should reproduce, at a distant place, corresponding sound vibration. Reis knew that a drum-head or diaphragm, when vibrating, must constantly vary the pressure upon it of any body in contact with it, and he employed that device to vary a current of electricity.

It has been denied that it was then a matter of common knowledge that differences of contact pressure made a difference in an electric current, and such knowledge has been proclaimed as a discovery of later days; but since batteries were invented, it has been known that proper contact is one of the elements of efficiency for an electric current, and every student in electricity learns this among his first lessons.

The material which Reis employed for his varying contact was platinum. One of the specific devices which he used, and there were several of them, was a cubical box having a membrane diaphragm at the top, and a mouth-piece in connection with the inner part. On this membrane was fastened a strip of platinum, and a small piece of platinum wire rested upon this strip, completing the electric circuit. This is the typical transmitter which is usually shown in the market, and which is pointed to when Reis's work is mentioned (a transmitter of this form was exhibited, it being one made by Albert in 1863, Albert being instrument maker for Reis).

Reis, however, did not confine himself to this form, but made several forms, one of which had a shallow chamber, and is represented in diagram No. 1.



So much for Reis's transmitter. For a receiver he adopted, at first, the same receiver which was invented by Page; a straight rod of iron, surrounded by a coil of wire in electric circuit with the transmitter.

This receiving magnet he had mounted on a box for resonant effects. The question was: Would this receiver receive? There is no dispute about that, so far as the principle is concerned. What results did Reis get from that? Evidently very meagre—and why? The whole thing was set on a box on a table with the evident expectation that it would make as loud a sound as ordinary telegraph instruments made. But it would not do it, neither will any receiver that has yet been made. In order to utilize the best receivers we have to-day, it is necessary to box them up. But Reis did not stop with that receiver. He made another, which embodied still a different principle.

It seems a remarkable thing that people, when speaking about Reis's transmitters and receivers, refer only to his first instruments, quite ignoring his later ones.

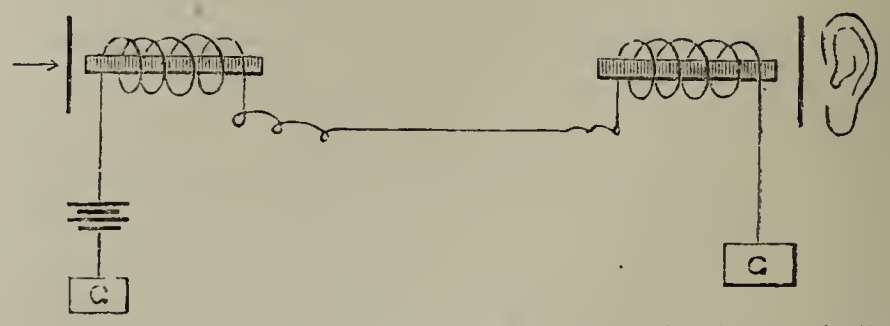
He invented a receiver, in which an armature was placed in front of an electro-magnet in order to utilize the magnetic induction to produce the vibratory motion of the armature. (See Diagram 1.) This was used in 1863.

Then let us see what it was that Reis did.

He invented a transmitter which would vary the strength of a current of electricity by the varying degree of pressure which was brought about between the contact surfaces, and, as was before stated, whether or not there was entire break of contact under such conditions as these depended solely on the amplitude of the vibrations of the diaphragm. It was not necessarily broken at any time when in use. The speaker could testify that the instrument would talk and would talk well. The identical instruments employed by Reis would do that, so that Reis's transmitters would transmit.

Secondly. His receiver would receive, and Reis did transmit and receive articulate speech with such instruments. There is no doubt about it at all. This system the speaker said he should call *Reis's system.*

In 1876 Prof. A. G. Bell brought forward another system, quite distinct from this. He proposed (and the lecturer thought he was the first in the world to propose) to speak to the armature of an electro-magnet with the expectation that somebody else listening to the armature of another electro-magnet in the same circuit might be able to hear the spoken words. His device they were all acquainted with. He had made a diagram of this (Diagram No. 2).



Professor Bell proposed to have in one circuit two similar instruments, each provided with an armature in front of its proper pole, and he expected that words spoken to one armature would be heard by a listener at the other end. But the principle involved in this was different from that of Reis. In this case the two magnets were included in the same circuit with a battery, and any motion of the armature in the one would vary the current on the line. This he said was a new system.

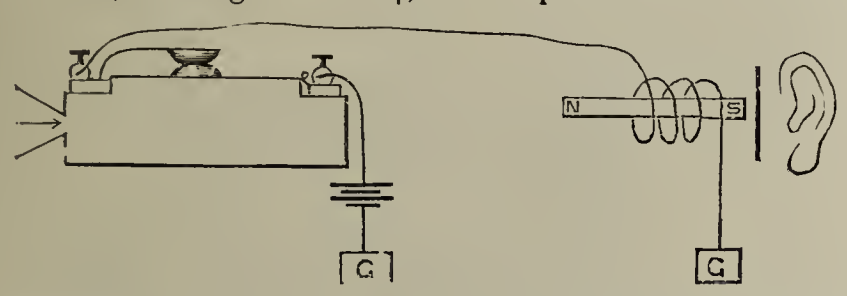
An improvement on that system was soon made, in which permanent magnets were substituted for the electro-magnets

and the battery was dispensed with, as illustrated in diagram No. 3.

This was an invention of his own, in 1876. But the instrument, as it was at that time, was very limited in its applications. Under certain conditions it could be used for a distance of twenty miles, but it was not efficient, and it became necessary to find some means to increase its usefulness, and men began to turn back towards the original Reis system, some seeking to improve his transmitter, while others sought a substitute for it, in order to make the telephone of more practical use.

Among the latter, Mr. Edison proposed to employ such relatively poor conductors as plumbago and lampblack, the conductivity of which varied with the degree of compactness to which they were subject, as illustrated in the well-known Clerac's tube, and he thus developed what is commonly known as the Edison transmitter.

Professor Hughes discovered that gas carbon, when in an unconstrained state, was as efficient or more efficient than any other substance appropriated to that use, and now, when the gas carbon is made to take the place of the platinum in the Reis instrument, we have one of the most efficient transmitters that has yet been invented. He had now, in diagram No. 4, what represented the identical



instrument—invented by Reis—in all its features except that carbon was used in the place of platinum, and he (the Professor) would say that this instrument was as efficient a transmitter as had ever been invented, and furthermore it was coupled up with the magneto apparatus, and was what is known as the present Bell system. They would see it was the original Reis system, plus a permanent magnet.

There was another device, which to some would seem the same as the foregoing, but it was worked upon another principle altogether, which might interest them to know more about. (The Professor here had recourse to the blackboard to illustrate the instrument he was alluding to. He here described the Rotaphone, and also described a sounder and a relay, which were adapted to telephonic work, all invented by himself. The instruments were exhibited.)

Having described these, he would now come to the particular one he had there to exhibit, and in order to lead up to that, he wanted to remind those who had experimented with so-called static electricity, that any one who has charged a Leyden jar must have noticed that it always emitted a sound. They could always hear it cracking and snapping, and it so continued until it was discharged. This had been known for a long time. The first experiments that he knew of, in which the sonorous effects of condensers in any other form than those of the Leyden jars were observed, were those of Sir William Thomson, about 1863, in which he had an air condenser in connection with some sub-marine cable; and he observed that as often as the condenser was charged or discharged it produced a sound, and the sound appeared, as he thought, to come from the air between the two parts of the condenser. Afterwards Dr. Wright coupled up two pieces of silvered paper, back to back, and connected them with terminals on a secondary coil, and that with a Reis transmitter—and he found that, by charging and discharging. he could make sounds loud enough to be heard in a hall of considerable size. I have never heard that articulate speech was rendered by Dr. Wright. Mr. Varley then employed condensers of considerable capacity for producing sound. The speaker was not well acquainted with these devices, but he did not understand that Mr. Varley got articulate speech from his arrangement, or that he attempted it. But although his (the Professor's) apparatus was in some respects similar, it was not true that he worked up to it from that direction. It occurred to him that if he should pass a varying current of electricity through a substance that electricity would decompose, and the decomposition of that substance should result in the liberation of gaseous material which would increase in volume, he would have the means of setting up vibrations. (The Professor then described his apparatus, illustrating it on the blackboard). This instrument consisted of a plate opposite another one, the space between

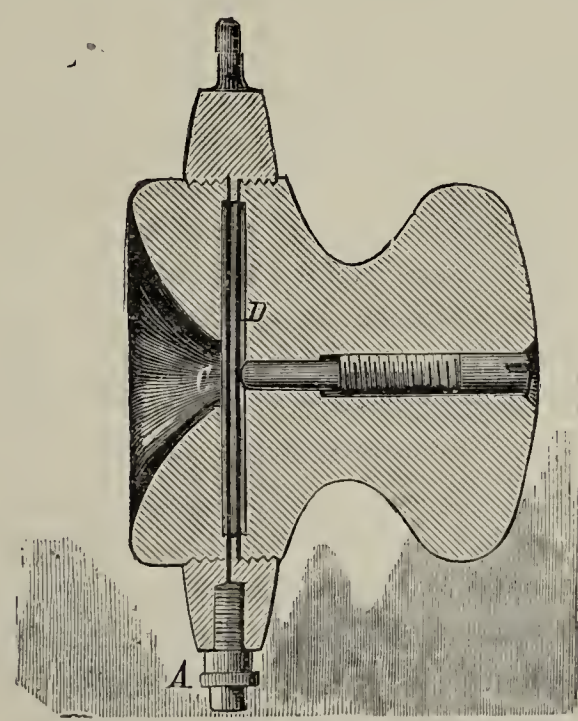


Fig. 8.

[In the diagrams as here given, electro-magnets are *shaded*, while permanent magnets have *indicated poles*.]

the two being practically water-tight. He supposed that the material he placed between the two would be decomposed. He put on an ear piece, and listened, and heard. He found one time, when he was at work at this, that for some reason the liquid had leaked out, and that he was still able to hear when there was nothing but air between the plates. He took the hint and worked out on that line, and developed from such conditions as those the present instrument. This instrument consisted of substantially the same parts as the previous one, excepting that the decomposable material was left out. He wanted to say something about the electrical condition present in this instrument. It had been known for a very long time, perhaps from the earliest days, that an electrified body would attract another body in its neighbourhood. (The lecturer illustrated this on the blackboard.) Let them suppose then that here was a wire which came from some source of electricity—here was a body, say a pith-ball. That body would be electrified. This is a case of action at a distance, a physical condition which was extremely interesting for many reasons. There was a great deal involved in that kind of action which they, as physicists, had to look after. If, instead of putting the pith-ball there, he should put a plate, separating the two by means of a non-conductor, the electric pulsations in the one would result in attraction upon the other. In describing this it was said that one was inductively electrified; but the effect was to make the plate move. The strength of this attraction would vary with the kind of material that was employed, with the electro-motive force which was acting upon this plate, and also with the shape and physical conditions of it. Suppose they looked for a minute or so at the necessary conditions for getting a maximum amount of sonorous work out of a device of this kind, *i.e.*, a condenser. It must be that the plate was free to move, free to vibrate. Suppose, then, they were using an ordinary condenser, made in the way he would show on the blackboard, in which they had the plates like those in the diagram. Now the electrical condition here would spend itself on them, and they would have, not maximum condition, but the very minimum. These plates must not touch each other if they were to get the best results from them. The vibrations occurred with such great rapidity in articulate speech that it was an essential condition for the maximum amount of work that the plates should not be capable of absorbing to any appreciable extent the electrical conditions. He had worked with plates of all sizes, from those not larger than the end of one's finger to those, perhaps, 2 ft. in diameter.

Now he would say a few words about the different conditions at the transmitting ends. In the four diagrams he had shown, only the essential features had been drawn. In No. 4, he was quite aware that an induction coil was used, but it was not an essential thing. In No. 5, which was his system, it was essential that he should have the electro-motive force. If he connected up an instrument of this sort with No. 4, no appreciable result would be got from it, because the electro-motive force there is not sufficient. There were two or three

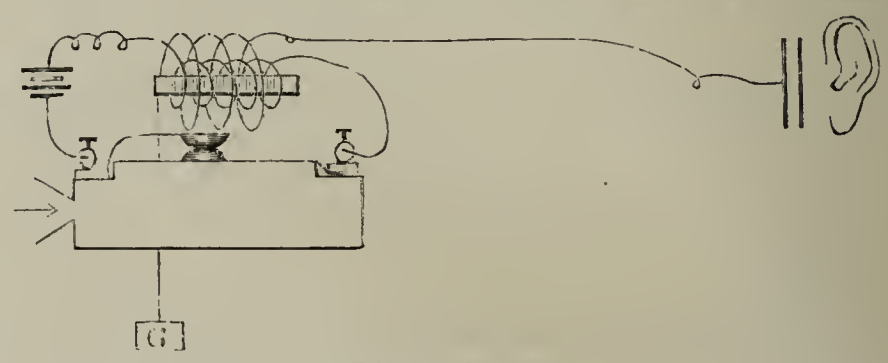


Diagram No. 5.

ways in which they could use a transmitter. One of them was by means of electric machines. Let them suppose that instead of a battery being the source, it was an electrical machine which would give a jumping spark. He could get a current of electricity in this way which would pass a certain distance in air. [Illustrated by diagram].

If, however, he took an ordinary induction coil having a sufficient number of turns, he would then have the means of getting the high electro-motive force essential for working this instrument. In that case he would have the device shown on the board, in which was a Reis transmitter connected with an induction coil, connected with his receiver. In this case the undulatory current in the primary circuit set up varying electro-motive force in the secondary coil to work the instrument. External resistance was a very small factor indeed. The length of wire through which it would work was almost unlimited.

He would now exhibit the working of these instruments.

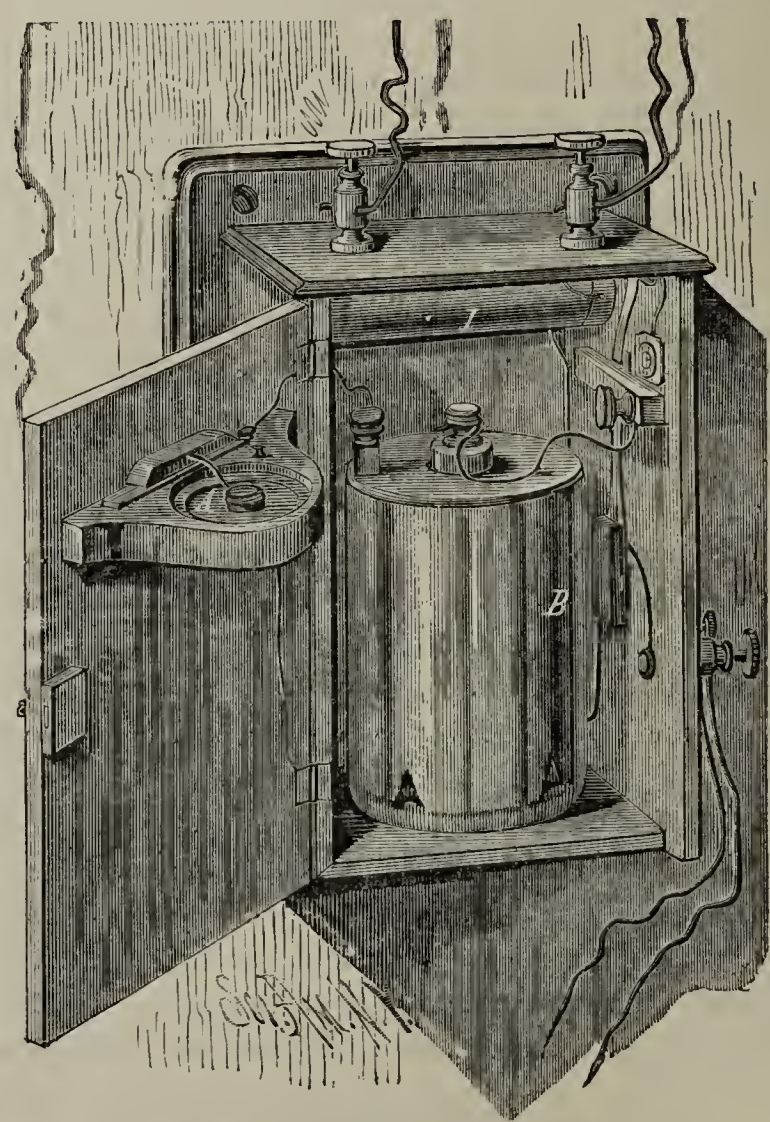


Fig. 6.

He had set up several instruments there in working order, which he would show.

Figures 6, 7, and 8, show the transmitter, the receiver, and a cross section of the receiver.

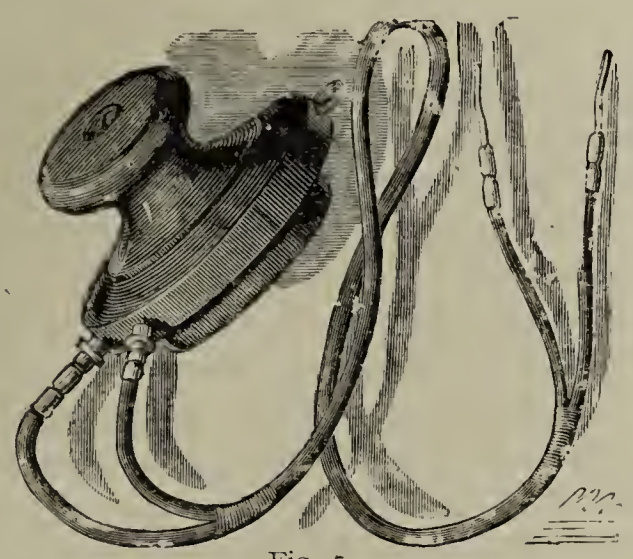


Fig. 7.

Arranged on stands in different parts of the hall were twelve receivers, all connected with a single transmitter, in which was employed a single small bi-chromate cell. Counting, whistling, and a cornet solo were distinctly heard in all parts of the hall.

He then showed that it was not necessary to have a return circuit, for a receiver was shown which had but a single terminal, and the sounds from this instrument were not inferior in loudness to the two-terminal receiver.

He next said that it was not necessary that there should be even two plates, and he showed an instrument having but a single plate and terminal, to which the President was invited to listen, and he reported that he heard perfectly with it.

And lastly, the Professor said he had discovered that even connection with the line was unnecessary, and he therefore quite disconnected a receiver from the line wire, and handed the instrument to the President, who, at a distance of several feet, reported that he heard perfectly, although the sound was much weakened.

The speaker thought it might be well for him to say a few concluding words (regarding this system which he had just shown them) concerning its advantages, and why he described it as a new system. The Reis system was one in which the electricity was transformed into magnetism, and this into the vibratory motions of the plate. In this system the electric transformation was but a single one, the electricity being transformed immediately into the vibratory motion without the intermediation of magnetism. On account of the electro-motive force, the matter of resistance does not enter it as a factor, as in electro-magnetism. There, of course, Ohm's law was applicable, but in this case it was not—at any rate within the limits of figures which they were capable of manipulating.

The cost of the apparatus was nothing very great. It was about the same as the other system. As to what it would do, he would simply tell them what he had done with it. He had had a line between his lecture room and his residence—a line of about half a mile in length—which for two years had been worked on this system, and it was going as well then as when he put it up two years ago, and the single cell of battery which had been used had received no attention except to add a little water. He had also used it on tolerably long lines, one of 40 miles, and one, the telegraph line of the Rapid Telegraph Co. between Boston and New York, 256 miles in length. This last one he talked over during a storm, expecting a loss from leakage, but he was able to hear very distinctly. As to what it was capable of doing beyond that, he had not had opportunities of trying.

At the conclusion of Professor Dolbear's address, which was received by the audience with marked expressions of approval, the Chairman expressed his gratification and appreciation and called upon Mr. W. H. Preece. The latter gentleman warmly commended the address, and declared his interest in the invention of Professor Dolbear, because of its practical importance to the world, as well as its scientific novelty. It should be the policy of the Government to foster and encourage all such advance in a science so important as telephony, and if the Patent Laws of Great Britain are not such as to secure that result, Mr. Preece remarked that it was time they were altered. He moved the thanks of the Society to Professor Dolbear for his valuable paper. Professor Carey Foster seconded the motion in a few well chosen remarks, and the Chairman declared the motion unanimously carried.

ON THE PROPERTIES OF IRON AND STEEL.

The Tables on the above subject are unavoidably left over till our May number.

Lord Colville has written to say that many newspapers, notably *The Times*, have entirely misrepresented his remarks on Earl de la Warr's bill, to render the adoption of continuous brakes compulsory. His lordship recommended Earl de la Warr to *withdraw* the automatic clause.

AUTOMATIC COMPRESSED AIR-BRAKES *VERSUS* AUTOMATIC VACUUM BRAKES AND NON-AUTOMATIC BRAKES.

IN our February number we published Colonel Yolland's report on the Blackburn Collision on August 3rd last. The following comments on this report have been made by the Westinghouse Brake Co. in a recent pamphlet, entitled "Automatic Compressed Air Brakes *versus* Automatic Vacuum Brakes and Non-Automatic Brakes":—

1. The strong animus displayed throughout by Colonel Yolland against the Westinghouse brake, as shown, chiefly by his ignoring all facts and probabilities which told in its favour, at the same time that there was no evidence whatever, except that of the engine-driver and fireman, against it; by his readiness to accept all the engine-driver said as true, in the face of facts which rendered his evidence valueless; by a strained endeavour to make everything fit his own theories; and by a too apparent desire to convey the idea that the collision resulted in some way from the *automatic* nature of the brake.

2. Every one must be struck by the introduction of so much irrelevant matter concerning automatic brakes generally, and about the so-called failures of the Westinghouse brake, by applying itself at improper times; whereas he alleges the Blackburn collision to have been caused, on the contrary, by the failure of the brake to act when required; a class of failure which is well-known to be peculiar to, and inseparable from non-automatic brakes, on account of their defective principle.

Colonel Yolland has, moreover, so contrived to mix up the Blackburn collision with this other irrelevant matter, and so used the alleged failure of the brake as a foundation upon which to build his arguments, that it will be necessary first to explain how the collision really came about, and more particularly is this required on account of the use to which the report has been put by the opponents of automatic brakes.

A train from Liverpool, while standing in Blackburn station, was run into by an express train from Manchester, at a speed of from 25 to 30 miles per hour, killing 8 and injuring 64 people. The signals which ought to have protected the Liverpool train were off at the time, and this, to most people, would be sufficient to account for the accident. The driver, however, after having had time for reflection, said that the brake failed to act; but he did not say this (as will be seen) immediately after the accident; and, although there is not the slightest evidence either positive or negative to support his statement, Colonel Yolland concludes that this man spoke the truth. At the same time, there is evidence, both positive and negative, that the brake acted as perfectly (when it *was* applied) going into Blackburn as it had done at the previous stations on this journey, and it would have prevented the collision if it had been applied in time.

Several passengers by this train gave evidence before the coroner in Colonel Yolland's presence, and swore to feeling the brake act distinctly on the different carriages in various parts of the train. The following testimony alone is conclusive:—

William Evans: "On reaching the West Cabin I felt the deep grinding bite of the brake on our carriage. We came into the Blackburn Station at as rapid, or more rapid speed, I should say, than at any period of our journey between Manchester and Blackburn. Immediately after the collision, and after we had attended to the injured, I spoke to the driver of the train. I asked him, 'Why in the world did you bring that train into this station at such a rate?' He replied that he could not see the train standing in the station, nor could any other man, until he was coming into the station;" and, "The driver did not say to me that the Westinghouse brake would not act."

The guard, whose van was the third vehicle from the engine, also made an important statement. He said in his evidence, "I opened the valve of the Westinghouse brake in the van after we had passed the West Cabin, and *I did not hear any rush of air.*" Now the brake is allowed to have been all right at Over Darwen, the previous stop, and $5\frac{1}{2}$ or 6 minutes before reaching Blackburn; and the driver says there was 80 lbs. of air in the gauge passing the point where he applied the brake, less than 1 minute from the time of collision. If, therefore, the guard found no air on entering the station, it was clearly because the driver had already let it out of the brake pipe; that is, had applied the brake, although he had done so too late to be of material use.

It is a fact, moreover, that the brake acted on the engine and four uninjured carriages even after the collision, and that nothing was found amiss with the brake-couplings, valves, &c., on the injured carriages, or in the state of the train generally, to account for the accident in any way from any failure of any part of the brake.

We maintain that, having regard alone to the fact that the signals were not at danger, it is quite superfluous to turn to the brake as a cause of the collision. The driver states that on the few occasions when he had run to Blackburn before, the station had always been clear; that

he had never taken that particular train into the station previously; that he had himself worked the brake only two or three times before without any proper instruction; that his usual place for stopping was the further or east end of the platform (at a point about 165 yards past the point of collision); and that he expected by the state of of the signals to be able to do so on this occasion. And Colonel Yolland allows in his report that the driver was quite justified in his endeavour to get to this place, so far as the signals are concerned.

Under these circumstances, then, there is nothing to justify the assumption that the brake in any way failed. Had only the last home signal been at danger, had the express then run 240 yards past it, and had it then struck as it did another train at 25 to 30 miles per hour, there might have been grounds for Colonel Yolland's conclusions, but as it is there is no excuse whatever for them.

How the collision occurred is perfectly clear. The driver, having just decended a steep incline 3½ miles long, was running at a reckless speed up to the station, intending to proceed to the further end of the platform as usual, and to make a smart stop, similar to what he had been doing at previous stations, when suddenly he found another train had got there first. He applied the brake, whistled, and reversed his engine. but for the want of about 80 yards further distance, within which he could easily, by means of the brake at his command, have brought his train to a stand, came into collision with the unprotected train already there.

This view, however, did not commend itself to Colonel Yolland. He preferred to accept the statement of the driver that, on trying to apply the brake (at a point about ½ a mile from where he intended to stop), some mysterious irregularity, the nature of which cannot be discovered, suddenly occurred to the brake. For the purpose of justifying his theories, Colonel Yolland made a series of experiments with a similar train to the Manchester express, the brake always being applied at the spot indicated by the driver. In one experiment, when the brake coupling was purposely separated between the first and second carriages (as had been suggested might have been the case at the time of the accident, without any evidence to justify the supposition) the train stopped 10 yards short of the point of collision, from an initial speed of 50 miles an hour, as against 40 mentioned by the driver as the speed on the day of the collision. At last, by cutting off the brake from the train, and allowing it to act upon the engine wheels only, the point of collision was in one experiment passed. Colonel Yolland concluded, therefore, that the collision was caused by the brake refusing to act, except upon the engine wheels; notwithstanding the positive evidence that the couplings between the engine and train were found properly connected after the accident. The last-mentioned experiment was not made under circumstances stated by the driver to have existed, but it seems to have been necessary to confirm Colonel Yolland in the fixed conviction with which he began, conducted, and concluded the inquiry, viz., that the brake had failed. None of the experiments made, however, were of any sort of value, for the same results might have been obtained by running close up to the station, and then applying the brake over the whole train.

Colonel Yolland's theories did not find much acceptance from the Coroner's jury, for, as a result of the experiments and the evidence, they in their verdict entirely ignored the brake, and found, as was apparent to those who closely, and with an unbiassed opinion, followed the evidence from the first, that the collision was caused solely by the system of working the signals, and by the recklessness of the driver.

The fact, that the Westinghouse Brake Company called no witnesses, is thus remarked on by Colonel Yolland, who says:—

"I was prepared to hear what any witnesses they (the Westinghouse Company) might desire to call could state, as to any facts bearing upon the case, or to receive any statement which they might think proper to make, after hearing all the evidence, and noting all the experiments which were made, and I informed Mr. Westinghouse that I would delay making my report for ten days as he was obliged suddenly to go to the continent."

As to this remark, it may be mentioned that Colonel Yolland was so strongly prejudiced against the Westinghouse brake that he even went so far as to say in substance to Mr. Westinghouse that any statement made by him would not have weight; and, in reply to Mr. Westinghouse's remark that he could produce passengers who had felt the brakes upon their carriages on entering Blackburn station, Colonel Yolland said that he would not believe any witness he might present who would make such an assertion, because it was impossible for any one to tell whether a brake was acting upon the carriage he was riding in or not. We may add that, after due condsideration of the evidence which had been taken, both before himself and the Coroner, and the results of the experiments, coupled with the verdict of the Coroner's jury, it was felt that we should derive no benefit from accepting Colonel Yolland's offer, and laying any statement before him. It seemed impossible to this Company that Colonel Yolland could so far ignore the facts and probabilities, and allow his antipathies to lead him to such erroneous conclusions.

Nothing further, perhaps, need be said as to Colonel Yolland's allegation of the failure of the brake; but Colonel Yolland has, as we have said, discussed a good deal besides the Blackburn Collision in his report, and as it concerns the main subject of this paper, we may follow him a little further.

Much of the irrelevent matter before referred to, amounts to a condemation of both automatic and non-automatic con-

tinuous brakes. Now the question of automatic, *versus* non-automatic brakes, is one of principle only, and Colonel Yolland cannot consistently condemn the principle of the former, both on account of its liability to go on when not wanted, and also for refusing to act when it is wanted; yet this is what he actually does. Indirectly, too, he very effectually condemns non-automatic brakes on account of their inability to stop trains in case of a break-away, and for giving no indication to a driver of a coupling having come undone. Though clearly not what was intended, Colonel Yolland's report thus furnishes strong arguments in favour of the principle of automatic brakes; his conclusions in effect being:—

(1) That the collision was caused by the separation of a hose connection in the front part of the train in such a manner as to render the application of the brakes on the rear carriages impossible; (2) That any brake which may be liable to fail to act, in consequence of a brake coupling coming apart so as to render the brake inoperative, should not be used on railways; and (3) that brakes which may fail as above are dangerous, because the train may then overrun the intended stopping place, and thus cause a collision.

We have always contended that any brake so constructed that the couplings can come apart, and thus render the brakes useless, without warning to the driver, is a dangerous appliance, and we welcome Colonel Yolland's support in favour of these principles, and consequently in favour of automatic, as against non-automatic brakes.

The difficulty of our opponents in this case, lies, of course, in the fact that the brake in use was automatic, while the failure suggested was one peculiar to non-automatic brakes. If what was suggested took place, and a coupling came apart, and by closing the valves, gave no warning to the driver, the brake in question was thereby only reduced temporarily to the level of a non-automatic brake, the essential principle of which is that its failure *must* occur without proper warning.

Colonel Yolland makes the extraordinary statement that the Westinghouse brake connections "frequently (!) become uncoupled" without indication to the driver. How many cases would justify the word "frequently" we do not know, but can only say, that since the Board of Trade Returns have been published—June, 1878—only two of such cases are mentioned, against scores on the part of other brakes. In view of this fact, and considering the opinions he has expressed, it would only have been fair, and certainly more relevant than a good deal in the report, if Colonel Yolland had referred to these other brakes and condemned them in proportion to their liability to become useless when required to prevent an accident. For the six months ending June 30, 1881, there are no less than 80 cases actually reported in the Board of Trade Returns, of the Smith Vacuum Brake alone, having failed without warning, on account of the couplings coming undone or other equivalent dangerous failure.

We were, however, so impressed with the use which was made of the two instances of alleged failure before referred to, and saw so plainly that, under similar circumstances again arising, we should be laid open to the same accusations, that we promptly decided to make a complete change from the automatic coupling back to the old form with cocks: so that, in future, any such theories as those advanced in this case will be impossible; for should a pair of couplings be separated from any cause whatever, after the train has once been properly coupled up and charged, the warning which Colonel Yolland considers so essential will unfailingly and unmistakably be given to the driver.

There were present at Colonel Yolland's investigation the manufacturer of the Smith Vacuum brakes, and the brother of the manager of the Vacuum Company. The latter presented a partisan statement of brake failures prepared by the Vacuum brake Company, which Colonel Yolland received, saying he would accept any statement they might wish to make which would throw light upon the subject of the Blackburn collision. These gentlemen would probably have been better able to speak as to the before-mentioned failures of their own brake, and would have served their own interests better by employing their spare time in remedying some of its defects. The Vacuum Brake Company have never ceased to make use of Colonel Yolland's report, ever since its publication; and we consider we have good reason to complain that Colonel Yolland should have allowed an antagonistic Brake Company to have thus been represented, with such obvious intentions of influencing the conduct of his inquiry.

Two cases are mentioned in Colonel Yolland's report, where trains fitted with the Westinghouse brake over-ran stations, viz., Stanningley and Dover. The former is in the Board of Trade Returns, and we need only say that the circumstances were not analagous to those at Blackburn, and were easily accounted for. As to the case at Dover, which Colonel Yolland calls a "somewhat similar case to that at Stanningley," Colonel Yolland showed our representative a letter he had received from Mr. Kirtley, the locomotive superintendent, on this subject; and it certainly did not justify such a statement. The letter was to this effect, viz., that Mr. Kirtley had not reported the occurrence to the Board of Trade, because he did not consider it was owing to the failure of the Westinghouse brake; that the driver had not reported it as a failure of the brake; and that he decided to give the brake the benefit of the doubt. Colonel Yolland's reference to this case, and his omission of this explanatory letter, are sufficiently indicative of his bias.

In the interest of safety on railways, Colonel Yolland, again, should not have singled out one brake in particular. He would have found from the Board of Trade Reports on

Accidents, that there had been six collisions resulting from the failure of the Smith vacuum brake, and he should have censured this and other brakes, instead of the Westinghouse alone, if censure were necessary.

After such statements as have been criticised, it is almost with astonishment one reads that an automatic brake is required sometimes, even in Colonel Yolland's opinion. As, for instance, when a train breaks into two parts, so that the rear portion may be prevented from running back down an incline into a following train, or forward into the front part on the speed being slackened. Colonel Yolland has himself, indeed, on the occasion of such a case as this occurring near Blaby junction on the London and North-Western Railway, made the following remark in his report (dated 26th December, 1877) on it to the Board of Trade: "The collision would not have taken place at all if the train had been fitted with an automatic brake."

The result of this brief analysis, then, is that we find Colonel Yolland has (1) directly condemned non-automatic brakes, because they give no warning to the driver on a coupling coming undone, and thus rendering the brake useless; and indirectly, this is clearly an excellent argument in favour of automatic brakes. (2) He has directly advocated automatic brakes, because they are wanted in case of a breakaway; and indirectly, this is an excellent argument against non-automatic brakes.

It is with reluctance that we criticize the report of Colonel Yolland, but we are compelled to do so in consequence of the hostility he has shown to the Westinghouse brake by his remarks during his inquiry, by his mode of conducting his inquiry, by the remarks in his report, and by his going out of his way to introduce material entirely outside his inquiry, all of which fully justify much more than we have said.

Colonel Yolland might, we think, have remembered that the Westinghouse brake complies more nearly than any other brake with the conditions laid down by the Board of Trade, of which he was the representative. And further, he should have hesitated to be so severe in his strictures, in a case where no positive evidence was forthcoming, on what is, at all events, an appliance intended to save life and property, and which the proprietors have for many years spared no expense in bringing to perfection.

A special Minute by the President of the Board of Trade was, as thought, in the first instance a sufficient refutation of Colonel Yolland's report, and we did not, therefore, sooner offer our comments upon it. And it is only on finding that report extensively circulated, without the Board of Trade minute, and made use of against us, in England and on the Continent, that we have at length been induced to prepare for similar circulation the present pamphlet.

OFFICIAL REPORTS ON RECENT ACCIDENTS.

Major-General Hutchinson has reported the result of his inquiry into the circumstances connected with the collision which occurred on the 11th August last at Ticehurst Road station, on the Tunbridge and Hastings branch of the South-Eastern Railway. This collision is to be primarily attributed to the 8 o'clock ordinary train from Hastings having been allowed to leave Etchingham station before "line clear" had been received from Ticehurst Road station. The line being blocked between Etchingham and Ticehurst Road, the train had been nearly stopped and then admitted to the Etchingham platform by the signalman's green hand-light. There being no up starting-signal at Etchingham, the signalman had then, in accordance with the usual practice, placed his hand-lamp showing a red light on the platform beside his cabin at the Hastings end of the down platform, where it could be (if properly placed) just seen from the engine standing at the London end of the up platform. It appears, however, that when the train was ready to start hand-signals passed between the guards and station-master, neither of whom had looked at the signalman's lamp; and the driver having received an "all right" starting-signal from the front guard, and concluding that one of the guards had, according as he states to be the practice, seen that the signalman's signal was showing "all right" started. His fireman states that he had looked back towards the signal-cabin but saw no light, though he did not inform his driver to this effect. Considering the imperfect signal arrangements at Etchingham station, that it was not easy for the driver of the up train to see the signalman's signal, that there were no direct instructions that he should do so, and that it seemed to have been the practice for him under similar circumstances to have taken the starting-signal from the guard, it seems to me that the station-master is most to blame for not having acquainted himself with the state of the line between Etchingham and Ticehurst Road before giving an "all right" lamp signal to the guard in charge of the train. Notwithstanding that the train was thus improperly allowed to leave Etchingham, no collision need have ensued had not the driver of the up ordinary train (no doubt off his guard, and not expecting to meet with any obstruction outside the up home-signal at Ticehurst Road) mistaken, as he says, the two tail-lights of the excursion train, which were standing about 140 yards outside the up home-signal, for the up home-signal and signalman's lamp at Ticehurst Road station. He was running slowly in, prepared to stop at the Ticehurst Road up home-

signal, and realised only, when some 50 or 60 yards off, that the lights he had thought were those of signal-lamps were really the tail-lights of the excursion train. He then used all the means in his power to stop, and struck the tail of the train at a speed not exceeding a walking pace. It is not easy to understand how the two *horizontal* lights at the tail of the excursion train should have been mistaken by the driver for a space of some 300 yards for the two signal-lights (one of which was about 10 feet above the other) had he been keeping a proper look-out ahead ; and I fancy, having seen the distant-signal at "danger," and being prepared to stop at the home-signal, he had not really looked ahead till a short distance before the collision. Even then, had he been provided with a continuous brake, he could probably have been able to avoid the collision. I trust that this collision will lead to proper starting signals being provided as soon as possible at those stations on this railway where they do not now exist, and without which it is hardly possible to work the block system satisfactorily. Meantime a distinct rule should be, I submit, adopted, warning drivers in all cases to see for themselves the block signals shown by the signalmen's flags or hand-lamps. The up distant-signal at Ticehurst Road, only 525 yards from the up home-signal, is not sufficiently distant for a line on which express trains run.

Major-General Hutchinson has also reported the result of his inquiry into the circumstances connected with the collision which occurred on the 9th August last, at Liffey junction, on the Midland Great Western Railway of Ireland. The primary cause of this very serious collision is to be attributed to the tender-brake of the engine of the Sligo train having been inoperative when the fireman tried to apply it near Ashtown crossing, more than 1½ miles from Liffey junction, where the train had to stop. The train was running at the customary speed of about 40 miles an hour when the fireman began to turn the brake handle, and when rather more than a mile from the junction he found, from the brake handle turning more than usual, that the brake shaft had become disconnected. On finding this out the driver states that he first whistled for the junction-signals and then for the guards' brakes, that he reversed his engine and gave it contrary steam about half-a-mile from the junction, and then again gave the brake whistle; the fire-man more or less agrees with these statements; but a permanent-way inspector, who was on the engine, believes that no brake whistle was given after the engine was reversed. The two guards with the train, one in the sixth vehicle from the engine and the other at the rear of the train, neither of them heard any brake whistle, but both state that they applied their brakes sooner than usual in consequence of the high speed when nearing the junction. No brake whistling was heard, either by the inspector on the Liffey junction platform, or by the signalman, or by the driver, fireman, or guard of the empty train. The collision took place on the Northwall branch, about 50 yards beyond the signal-cabin, at a speed variously estimated at from 15 to 30 miles an hour, the engine of the empty train being in slow forward motion into a siding joining the up-branch line with trailing-points. After the collision the horizontal bolt (1½ inches in diameter), for connecting the brake-shaft with the pull-rod of the brake-block of the tender, was picked up about three-quarters of a mile from the junction. The split-pin, which should have kept the bolt in its place, was gone, and the bolt must have been gradually working loose, and finally lost its hold between Clonsilla—where the brake had worked properly—and Ashtown crossing, where the fireman next tried to apply it. It is a question whether it is wise to trust the efficiency of a tender-brake to one split-pin. Although the failure of the tender-brake was the primary cause of the collision, the driver of the Sligo train might, I think, have done more than he did to check the speed of his train, and to arouse the attention of the Liffey junction signalman. The failure of the tender-brake was known to the driver when more than a mile from the junction, but nevertheless he did not reverse his engine until close to the distant-signal, about half-a mile from the junction ; nor did he keep open his whistle, which had he done, he might have attracted the attention of the inspector or signalman at Liffey junction in time to have had the facing-points leading to the Northwall branch set for the main line and the train turned along it, when there would have been more than a mile in which to pull up. The collision would not have occurred had the block telegraph regulations been attended to by the Liffey junction signalman. He says that he got the "be ready" signal for the Sligo train at 4.56, and accepted the train (with the "train on" signal) from Ashtown at 4.59, the empty carriage train not having crossed from the down to the up line till (at the very earliest) 5.2. Rule 14 states, that "on receipt of the 'train on' signal for a passenger train care must be taken that no train, engine, or vehicle of any description is brought upon or taken across the main line or lines until the train signalled has arrived at or passed the box." The signalman completely ignored this rule in allowing the empty train to cross after accepting the "train on" signal for the Sligo train, whereas the empty train should have been kept on the down branch line till the Sligo train had arrived at or passed his cabin. With a good continuous brake in the in the hands of the driver of the Sligo train this collision would never have occurred.

Major-General Hutchinson has also reported the result of his inquiry into the causes of the accident which occurred on the 10th November last close to Carnforth station on the Furness Railway. From the circumstances connected with this accident, there is but little doubt that it was caused by the signalman having shifted the facing-points before all the train had passed over them ; he probably did this between the pas-

sage of the rear wheels of the last carriage and the front wheels of the rear brake-van, the distance between which was about 14½ feet; the van was thus diverted for a short distance on to the goods line until it and the other vehicles were forced off the rails by the drag of the front of the train. This accident would have been prevented had the facing-points been provided with a locking bar. The Furness Company had no right to use these temporary facing-points for passenger traffic without having first obtained the sanction of the Board of Trade. As some length of time must still elapse before the alterations in progress at Carnforth are completed, the facing-points should be at once provided with a locking bar, so that a recurrence of a similar accident to the present may be prevented.

Major Marindin has reported the result of his inquiry into the causes of a collision which occurred on the 26th September last, at Maidstone station, on the South-Eastern Railway. From the evidence it appears that, shortly before 5 p.m., a special hop-pickers' train arrived at Maidstone from the Paddock Wood branch, and was, at the south end of the yard, sent through the station on the "back road," the proper up North Kent road, as the platform line was occupied by the 5.10 p.m. train from Paddock Wood at the south end of the platform, and the carriages of the 5.40 p.m. up North Kent train at the north end of the platform. In the ordinary course this special train would have followed the 5.40 p.m. train, but, as only the three rear carriages were occupied, the platform inspector decided to take off these carriages in order to attach them to the rear of the 5.40 p.m. train. For this purpose he sent the switchman, Farrance, to tell the driver of the engine of the 5.40 train, which was still in the yard. to bring his engine out to take the three loaded carriages off the rear of the hop-pickers' train. This was at 5.6 p.m., and Farrance, who had to attend to some points while the 5.10 train to Paddock Wood was running out, asked the locomotive foreman to tell the driver that he was "wanted out," but did not say for what reason. The driver started as soon as he was ready, thinking, he says, that he was wanted to go out to his own train, and he did not see the obstruction on the line upon which he was running at about five miles an hour, until he was within eight or ten yards of it, and although he at once applied his vacuum brake, he did not succeed in actually stopping his engine. Had he been keeping a sharp look-out he might have seen the rear of the hop-pickers' train for about twenty yards at the outside, but his fireman might have done so for over seventy yards if he had not been engaged in sweeping up his foot-plate, which he had no business to be doing at that time. This slight collision was due, first, to the omission of the switchman, Farrance, to give proper directions to the driver when he called him out, and secondly, to the carelessness of the driver in not seeing that his fireman was keeping a proper look-out when, from the nature of the place, he was unable to see far ahead himself. He had no business to take it for granted, as he seems to have done, that he had been called out to go straight to his train, and the very fact that the station yard at Maidstone is not what it ought to be, either as regards the signalling arrangements, or the space available for working the traffic, ought to have made him all the more careful when moving about it.

Colonel Rich has reported the result of his inquiry into the circumstances connected with the collision that occurred on the 5th September last at Yeovil Town station. The collision was caused by the neglect of the Great Western pointsman, who was stationed at the block hut, at the south-west end of Yeovil Town station, whose duty it was to work the facing points which lead to the platform and to the goods yard at the west side of the railway. He lowered the signals to "all right," held out a green flag to call on the passenger train, and forgot to set the points right after a London and South-Western goods train had run out of the yard about ten minutes before the passenger train arrived. The arrangements at Yeovil Town station, and the divided responsibility between the servants of the respective Companies, are most objectionable and dangerous. The station requires to be re-arranged, the points and signals should be interlocked and worked from raised cabins, and each pointsman should have distinct and separate duties with undivided responsibility.

NOTES.

Non-Automatic *v.* Automatic Brakes.—We have been favoured with the following extract from the Board of Trade Returns, ending 31st December, 1881, on Continuous Brakes. The total mileage of the Westinghouse (Automatic and Simple Brakes) being 8,639,645; Vacuum, 11,535,392. It also shows the Simple Vacuum Brake faults to be on the total mileage of 7,888,176, 1 in 131,469 miles; Westinghouse (Simple) on the distant miles, 483,459, no failures; Automatic Vacuum Brakes, total mileage, 3,647,216, 1 fault in 52,858 miles; Westinghouse Automatic Pressure Brakes, total mileage 3,156,106, 1 in 15,245 miles. Upon these results it may be inferred that the Vacuum Automatic Brake as well as the Simple Vacuum Brake are in favour amongst the railway engineers: —AUTOMATIC BRAKES.—Westinghouse Automatic Brake: Great Eastern, miles run, 792,932; faults, 90. Great Northern, 16,750—12. London and South-Western, 19,593

—2. London, Brighton and South Coast, 2,428,266—89. London, Chatham and Dover, 131,351—27. Midland, 430,931—115. North-Eastern, 2,734,307—68. Rhymney, 38,868—0. West Lancashire, 23,008—0. Caledonian, 95,300—8. Glasgow and South-Western, 322,224—31. North British, 1,122,656—93. Total miles run, 8,156,186. Total faults, 535. AUTOMATIC VACUUM BRAKES: Great Western, miles run, 1,033,053; faults, 12. Midland (Clayton's patent), 2,550,317—56. Great Northern, 33,422—1. London and South-Western, 16,653—0. Taff Vale, 11,731—0. Dublin, Wicklow and Wexford, 2,040—0. Total miles run, 3,647,216. Total faults, 69. Total miles run with automatic brakes, 11,803,402. This shows for the Westinghouse, 1 fault per 15,245 miles; for the automatic vacuum brakes, 1 fault per 52,858 miles. Average, 1 fault per 19,542 miles. NON-AUTOMATIC BRAKES.—CLARK & WEBB'S: London and North-Western, miles run, 7,896,883; faults, 18. London and Tilbury, 4,482—0. North London, 853,998—10. Caledonian, 476,577—25. Belfast Central, 12,324—0. Total miles run, 9,244,264. Total faults, 53. SMITH'S VACUUM: Cheshire Lines, miles run, 431,561; faults, 3. Great Eastern, 136,864—0. Great Northern, 3,562,998—32. Great Western, 118,118—0. London and South-Western, 23,095—1. London, Chatham and Dover, 10,530—0. Manchester, Sheffield and Lincoln, 755,845—3. Manchester, South Junction and Altrincham, 92,681—6. Metropolitan, 758,830—3. Midland, 141,894—0. North-Eastern, 349,575—4. South-Eastern, 559,332—4. Taff Vale, 99,965—0. Great Northern of Ireland, 35,256—0. Great Southern and West of Ireland, 765,168—4. Sligo, Leitrim and Northern Counties, 37,399—0. Ballymena and Larne, 9,065—0. Total miles run, 7,888,176. Total faults, 60. WESTINGHOUSE (NON-AUTOMATIC: Metropolitan District, miles run, 483,459; no failures reported. Total miles run, 17,615,899. These show—for Clark and Webb's, 1 fault per 174,420 miles; for Smith's vacuum, 1 fault per 131,469 miles. Average of all three, 1 fault per 151,614 miles.

CHUBB & SON'S NEW RAILWAY SAFE, &c.—We illustrate (Fig. 1) a station-safe for securing cash. It is specially noticeable as embodying all the latest patents by this firm, resulting in a safe of extraordinary strength. The protection of traffic receipts in outlying districts is an important item in the arrangements of every railway company. To do this by the purchase of cheap and insecure safes is but poor economy, as was lately evidenced by the successful attempt of burglars on the station-safe at Shoreham, Kent. Curiously enough, the same band of burglars attacked—the same night—a Chubb's safe at Orpington, not many miles distant, and were quite unable to make any impression.

A perfect insurance demands a fair premium, and is eventually most economical. The construction of the safe is as follows:—

The sides are of rolled boiler plate, three-eighths of an inch thick, secured by countersink square rivets to a patented overlapping T-iron frame. Six bolts—three each at front and

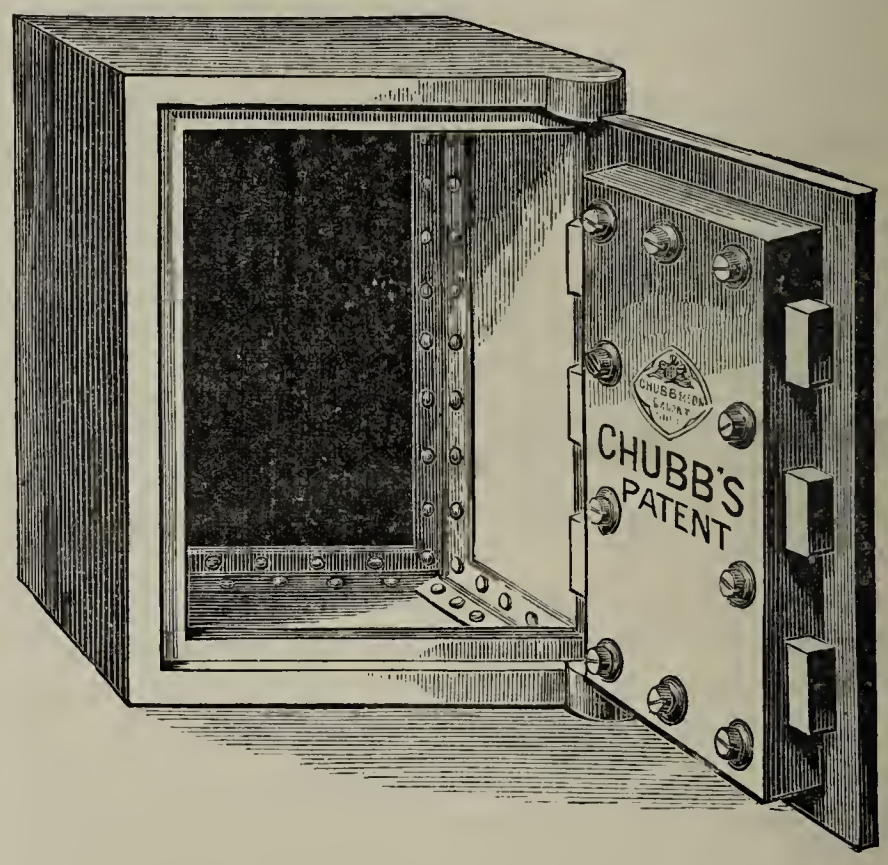


Fig. 1.

back—are thrown by the outside handle, and are secured by a gunpowder and acid proof lock. The construction of door and lock-case has lately been much improved by the use of a specially rolled section of wrought iron.

We also illustrate (Fig. 2) a Bessemer steel travelling Chest, made for the carriage of valuable parcels. In this

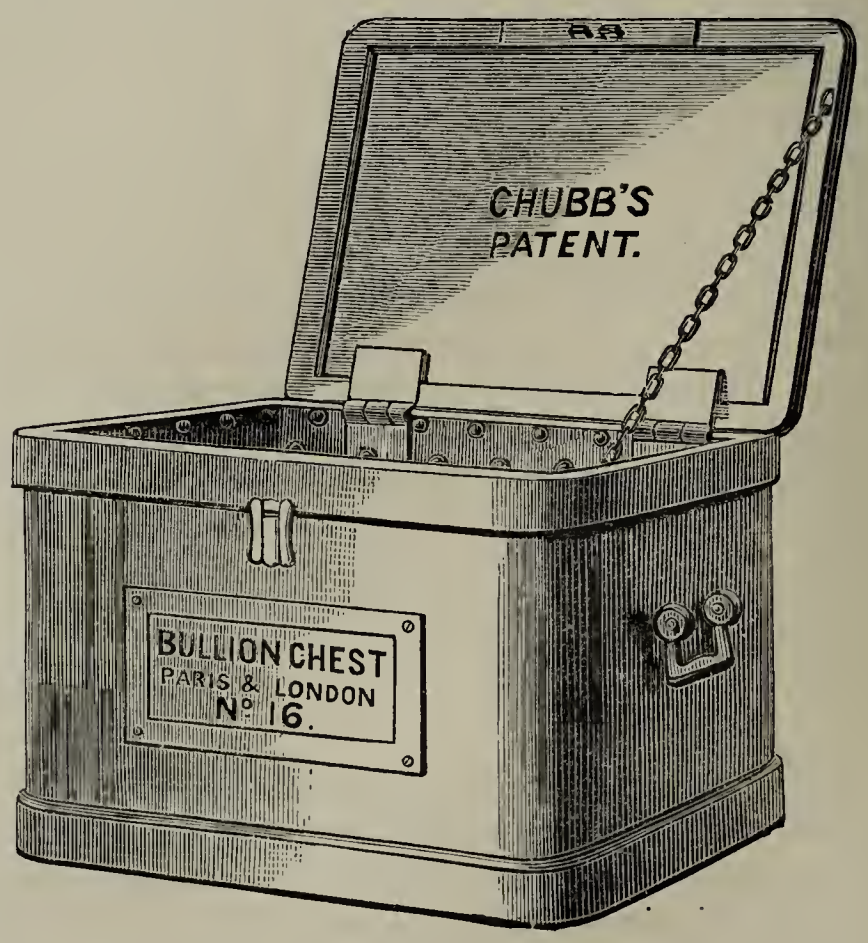


Fig. 2.

the corners of box are bent round, and the lock, containing Chubb's ingenious detector is dove-tailed into the front of the chest.

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THE BRAKE OF THE FUTURE.

WE published in our last issue some rather surprising comments made by the Westinghouse Brake Company on Colonel Yolland's uncompromising and truthful report of the circumstances which led to the terrible and fatal consequences of the Blackburn disaster. We gave publicity to those comments as an act of justice. It was desirable that our readers should be presented with both sides of a question of such grave importance, although it was painfully apparent that the Westinghouse Brake Company were ill-advised in permitting a document of such very questionable taste to go forth to the world. After an exceptionally long and full enquiry, Colonel Yolland expressed his opinion that the accident was caused by the failure of the Westinghouse brake. That opinion was the inevitable result of the facts elicited during the protracted investigation and carefully conducted experiments. The duties of a Government railway inspector are of a highly responsible character, and Colonel Yolland has deservedly won universal respect and confidence by the thoroughness and conscientious accuracy which has always characterized his enquiries and reports. With shame and regret, therefore, the Railway world has read the scandalous insinuations and indecorous abuse contained in the pamphlet alluded to. In dealing with a question affecting the safety of the travelling public, and one of a purely practical and scientific character, we cannot be too careful to exclude all personal and commercial considerations. The brake of the future will be selected by the verdict of practical men, based on the unassailable evidence of experience. Technical knowledge and the calm impartiality of true science are necessary to the ultimate solution of the Brake problem. Deeply impressed with this feeling, and fully aware of the numerous difficulties surrounding the subject of continuous brakes, we regard with distress the pitiable spectacle of a trading company endeavouring to force a brake upon railway engineers by mere verbosity and bunkum. It is monstrous to suppose that the men who have built up our splendid railway system and have brought our locomotives and railway machinery to their present state of efficiency—a pattern to the whole world—will be induced to alter their opinions by the schemes of a few financial operators. It is difficult to say what will be the precise form of the brake of the future, but we can form an idea of the general principle which will be adopted.

We have before us a book, recently published by the Westinghouse Brake Company, comparing their own brake with that known as the "Clayton" brake, and which is the standard brake used on the Midland railway. Of course this literary production shows the Clayton brake to be wrong in every respect, and the Westinghouse to be a marvel of mechanical perfection. Unfortunately, however, this pretty theory is upset by ugly facts. The Board of Trade returns on Continuous Brakes for the half year ending December 31, 1881, show that the faults in connection with the Clayton Brake have only been 1 in 45,541 miles, while in the Westinghouse they amount to 1 in 15,245 miles. Another significant fact is that the Midland Railway Company are rapidly fitting their rolling stock with the Clayton Brake, and are as rapidly stripping it of the Westinghouse Brake. These circumstances are not pleasant to men who have lavished their capital very liberally to get a footing in this country, but they do not justify gross mis-statements or vulgar personalities. Some two years ago, the Midland Railway Co. were threatened with an action at law for using brake apparatus, said to be an infringement of the Westinghouse patents. A statement of claim was put in, together with a list of breaches, but such awkward answers were filed by the Midland Railway Co. that the Westinghouse Brake Co. have not seen their way to proceed further with the case. This sort of intimidation or attempt at forcing a monopoly has been resorted to in other directions, but we have no doubt the companies so attacked will be quite competent to hold their own.

A glance at the commercial history of the Westinghouse Brake Co. will demonstrate the kind of financial machinery by which they expect to solve the brake question.

There is in Pittsburgh, United States of America, a Company styled the Westinghouse Air Brake Company, which for the sake of reference we will call Company No. 1.

We have had in England for several years an offshoot of this American Company, which is reported to have been very lavish in its expenditure for pushing its inventions, and thereby, if possible, to exclude all other inventors or owners of continuous brakes, having for its Vice-President Sir Henry Tyler, who advocates the use of self-acting brakes only, and which offshoot we will style Company No. 2.

For reasons, probably only known to Company No. 1, this latter Company has been transformed into Company No. 3, with the fabulous capital of half a million sterling in money and share capital, to be paid to No. 2, which in its turn will no doubt refund to Company No. 1 all the monies due to it during the years it has existed, leaving 38,500 shares of £10 each in the hands of Mr. Westinghouse as representing Company No. 2, such shares to be dealt out to "such persons and in such manner as the said George Westinghouse, junr. shall direct."

£385,000 capital handed over to the representative of No. 2, after payment of £115,000 in cash ! !

The questions arise upon what estimates can such a sum be demanded, and to what ultimate destination will Mr. Westinghouse direct the shares, and for such as may be sold for cash into whose pockets will that be directed ?

Having set out the three companies, we will ask the subscribers to No. 3 to contemplate their position as against what Companies 1 and 2 are ready to *say*, and how little they appear ready to *perform* when put to the *test*, as shown by contrasting :—

First.—The advertisements in America of Company No. 1.

Second.—Clause 7 of the Agreement of Sale by No. 2 to No. 3.

Third.—The language used in a circular issued in England by No. 2.

Fourth.—The suggestion therein as to Railway Companies investigating brake patents.

First.—The advertisement of No. 1 in America informs its would-be-customers that "a *guarantee* is given against loss from patent suits on the *apparatus* sold."

Second.—Clause 7 of the Agreement of Sale to No. 3 exempts the vendors "from any personal *guarantee* with respect to the *validity of the patents*."

Third.—By circular, dated 18th June, 1880, and forwarded by No. 2 to the Railway Companies, it claims to have what may be considered the sole right to make Self-Acting Pneumatic Brakes, and although in this circular *it is prepared to prove, &c.*, yet it has been exempted from *guaranteeing* patents sold to No. 3.

It says : "But we do insist, and shall, when necessary, be prepared to prove that this patent (No. 2,684 of the year 1871) secures the sole right of constructing and working Pneumatic Brakes *furnished with auxiliary reservoirs in any form*."

Fourth.—The American circular gives a guarantee, but the English circular of No. 2 says: "We submit it is likewise the duty of the Companies (Railway) to have the claims of ourselves and others examined by disinterested and competent advisers, and not in reliance upon any indemnity to compel a patentee to vindicate his rights by litigation."

Surely we have the same rights to guarantee our customers in England against patent suits as they have in America, and as is there done by Company No. 1 by process of advertisement.

The guaranteeing of apparatus sold in America may be due to one of two causes. First, there may be weak points in the patents, whereby they are open to be assailed by owners of other brake patents. Secondly, to guard against what may be an American process of annoying Companies not using the brakes of certain owners, by giving notice of assumed infringements of patents, in the same way that is practiced in England by No. 2, and on account of which process the Vacuum Brake Company has furnished several such indemnities, the first of which dates backwards for a year or two. A trial in court threatened by Company No. 2 against certain railways has been hitherto carefully avoided, and can easily be conceived that if £500,000 will not enable the vendors (Company No. 2) to guarantee the patents they transfer a trial in court might expose weak points which might be found to exist, and thus be seriously instructive to Company No. 3, it having acquired by purchase what are called patents, but which, more correctly defined, are only licences for litigation.

The tone of the paragraph in the circular of June, 1880, of Company No. 2, plus the fact of giving notices of infringement to various Railway Companies, and having since purchased several other brake patents over which the notices of infringements were meant to ride, contrast in a most peculiar way with the clause exempting the vendors from guaranteeing the patents to the purchasing company, No. 3. In conclusion, have the subscribers to the capital of Company No. 3 satisfied themselves as to where the engines and carriages are to be found in sufficient number to return such a capital after paying interest and working charges during the period necessary to fit them ? There would appear to remain little for this Company to do in England, as the principal Railway Companies have either extensively fitted their stock with brakes, or have decided not to take the air pressure brake, now the property of Company No. 3. Moreover, this is not the universal brake, *and the vacuum brakes are most successfully competing with it; if it had been, for the time being, the universal brake, it would require great forethought and investigation to be applied before paying such a price for patents and goodwill in these days of invention.*

It may be interesting to take a rapid glance at what those of our principal railways who run in communication with

each other are doing in the way of fitting their stock with brakes.

Of the Midland we have already spoken. They are fitting rapidly with the "Clayton" brake, which is very simple in construction, self-acting, quick in action and readily understood by all those connected with it.

The Great Northern and Manchester, Sheffield, and Lincoln have been faithful to their first love in the shape of the simple vacuum brake, which has fulfilled every purpose for the last five years, and which we understand is exceptionally reliable. All the new stock is being fitted with a tell-tale arrangement in connection with the brake, so that the driver and guard are able to see the exact state of the brake. While a vacuum of about 2 inches is maintained in the train pipe, a small disc displays itself both to driver and guard, on which are printed the words "Brake Right." In the event of any couplings being left undone, the signal "Right" is not given, and the driver does not leave the station until everything is made good. The advantages of this maintained vacuum are that it tends to keep all couplings tight, and the air is more easily exhausted from the train pipe, as it is, to a certain extent, already in motion, and it is calculated that a saving of about 15 per cent. in the time of stopping is thus attained.

The London & North-Western Railway are fitting up with the simple vacuum brake, similar to the Great Northern, except that Mr. Webb has gone a step further with the tell-tale arrangement, and made it also a means of communication between passengers, driver and guards. The Great Western Railway have decided upon the automatic vacuum brake, and are fitting their stock with a somewhat similar arrangement to that adopted on the Midland Railway. The North-Eastern are using the Westinghouse brake on their branch lines, but on the through traffic are still continuing with the Simple Vacuum Brake.

The Lancashire and Yorkshire Railway have been very enterprising on the question of brakes, and have thrown the matter open to the fullest investigation. They have tried the Eames, Saunders, Westinghouse, and Automatic Vacuum Brakes; and, after lengthened trials, in the shape of practical every-day working, have come to the conclusion that the Automatic Vacuum Brake is the simplest and most reliable, and have, therefore, adopted it. We understand that it is intended to follow the course adopted by the Midland Railway, and remove the Westinghouse Brake, since the fatal collision at Blackburn.

The present aspect of the brake question is clearly one of a hopeful character. It is evident that we are not to be tempted by the seductive dollar, frightened by vituperative pamphlets, or forced by vexatious litigations into the adoption of an unreliable apparatus. The hour is approaching when railway companies must, for the most part, decide on a general principle, and the brake of the future will be of a form selected for efficiency and simplicity.

EDISON'S ELECTRIC MOTOR.

WE are indebted to a correspondent of the *New York Tribune* for some particulars of Edison's Electric Railway at Menlo Park:—

"The bed of the railway is as yet unballasted, so that a ride over its two miles of length is productive of unpleasant jerks and bumps. From the building next to the workshop at Menlo Park, where the steam engine and dynamo-electric machines are placed, a narrow plank walk leads across the field toward the woods in the rear. In this are the wires running from the dynamo-electric machines to the railway track, distant perhaps a quarter of a mile. Here the wires are noticeable, emerging from their casing and communicating with the rails. At first sight the track appears to differ from an ordinary railroad only in its gauge, which is three feet six inches. But a closer examination reveals three distinctive features. Where two rails meet they are joined together on the sides. On each side of the joint is a strip of copper, the ends of which are nickel-plated. Outside, these strips are screwed on flat bars of iron, the inner surface being also nickel-plated. Thus the current of electricity passes uninterruptedly from rail to rail. As this cannot be done at the switches, however, thin plates of copper are placed underneath the ends of both rails, so that the circuit is not broken. The frog in the switches is left out of circuit. It is only about three feet long, and as the driving-wheel of the engine is $4\frac{1}{2}$ feet in diameter the wheel passes over the frog with no perceptible interruption. Near the improvised engine house, which stands a short distance above the points where the wires connect with the rails, and about a quarter of a mile from that end of the track, the one passenger car of the railway stood Friday. The engine was running up and down the track, conveying Charles T. Hughes, the superintendent, and dragging a small platform car loaded with rails and ties. In appearance the engine is peculiar. If an ordinary engine was cut in two midway of the boiler, the forward half discarded, and the cab reduced in size, it would present a tolerably correct representation of the electric engine.

Its length is 15 feet and the height to the top of the cab 9 feet. Of course there is no smoke-stack.

"When a reporter took a seat in the cab the flat car had been left at the lower end of the track. Mr. Hughes raised the lever of the armature switch and the engine started. The engine ran evenly at the rate of 18 miles an hour. No arrangement had been made for running at high speed, as Mr. Hughes was using the engine simply in construction work, and it had been dragging loads of three or four tons. The four dynamo-electric machines at the central station were arranged in a multiple arc instead of in series, as is done to attain a higher speed. Two miles of the road have been completed, extending toward Plainfield, and a mile remains to be finished. At the lower end men were engaged in ballasting the track. The road runs from the engine house over a trestle about twelve feet high, through a swamp, and then through some fields, where there are cuts. Thus far the engine has done all that was expected. Yesterday and on several previous occasions it has proved itself equal to the task of drawing loads as heavy as could be applied, considering the character of the road and rolling stock. On Wednesday, with the dynamo-electric machines arranged in series, it ran at the rate of 41 miles and 4,000 feet in an hour, the highest rate that has as yet been reached. The rate of speed is estimated by the number of revolutions of the armature in the engine. The engine can be readily started, reversed, and stopped. In the cab, where the steam gauge is placed in the ordinary engine, is the armature switch. Raising the lever sends the current into the armature of the dynamo-electric machine in the front of the engine. If the lever is horizontal the circuit is broken, and if the lever is pulled down the current is directed into the armature in such a way as to cause it to revolve in the opposite direction, and the engine consequently moves backward. Mr. Edison intends to use an electric brake, but at present, in order to stop, the circuit is broken and an ordinary brake applied.

"In examining the engine more closely the reporter found two sheet-iron doors in the sides of what appeared to be the boiler, so that an inspection of the interior was easy. In front is a dynamo-electric machine; running lengthwise are the two legs of a large magnet, and the remainder of the interior is occupied with shafts and belting. An interesting feature is the course of the current and its transformation into motive power. It is taken up from the rails by the rims of the driving wheels, and passes through copper clamps to the hub. Rubbing against the hub is a copper brush at the end of a horizontal rod, which has the position of the connecting-rod of an ordinary engine. The current taken from the hubs of the driving-wheels by these brushes passes along the rods to wires which lead to the armature switch in the cab. From this switch the two wires are conducted to the armature of the dynamo-electric machine in front. This machine may be said to fulfil a double function—in absorbing and storing up electric energy as well as in developing it. When the armature and bobbins revolve the power is transmitted by belting around a pulley on the same shaft with the armature to a pulley on a shaft under the cab. Thence belting runs to a pulley on the shaft of the driving wheel. From the armature wires two smaller wires run to the coils of the magnet placed horizontally in the engine. These are the field wires, and through them the magnet becomes charged with electricity, and exerts a controlling influence on the armature which receives the greater force of the current. Without this magnet the armature would receive the full power of the current, and would become so heated as to be useless; but the electricity in the magnet, which can be increased or diminished at will, tends to draw the armature toward it, and in reality causes it to revolve.

"The total weight of the engine is four tons. The road, three miles long, will soon be completed and ballasted. The chief merits which Mr. Edison claims in favour of his electric motor are greater economy in fuel, in help, and in the wear and tear of material, and the absence of smoke and cinders. One central station for every ten miles of track is his estimate, the current being sent through the rails for five miles on each side of the station. After elaborate calculations in the case of the electric motor, as compared with the steam locomotive engine, Mr. Edison claims that the ratio of mean economy for both is 4 to 8.93, or $55\frac{2}{3}$ per cent. in favour of the electric engine."

THE PROJECTION AND CONSTRUCTION OF RAILWAYS—COMMERCIALLY AND PRACTICALLY CONSIDERED.

(*Continued from page* 91.)

WE should here mention that in some kinds of soil it has been found necessary to run *two* headings, one near the crown of the tunnel and the other at the bottom, in which case the timbering of the headings becomes more intricate. Such cases have occurred in the gault and the green sand formations, where the "poling" of the work requires not only studious care on the part of the resident engineer, but also a thorough knowledge of the work entrusted to him; in such a case a competent man should be found to watch the work as it proceeds. The engineer-in-chief will not permit his premium pupils to risk his own reputation, as they would do by being entirely guided by the contractors for the work.

It no doubt is perfectly right to permit young students in Government colleges to walk about the various works being carried out in England (prior to their departure for India or the Colonies) in order that they may wind up their preliminary theoretical training with the observation of the way in which works are actually carried out; and as they have, in such cases, neither responsibility for, nor personal interest in, the works examined, and therefore no anxiety but that to improve their own experience, they will use their critical acumen:—to observe the works not merely as perfect, but also to note apparent faults. Whether the faults are apparent or real subsequent practice will undoubtedly prove.

Typical sections of tunnels suitable for various descriptions of soil having been illustrated in a previous section of these articles—that upon Contract Drawings—we have here only to deal with the practical execution of such works.

We will, in the first place, take a tunnel cut in *solid* rock, requiring what is practically no lining; but this will also include the case of a tunnel through ordinary sandstone or oolitic rock, where the lining must be sufficient to prevent atmospheric disintegration, and to provide for the necessary drainage into suitable channels. In certain rocks, *apparently*, sufficiently homogeneous to resist ordinary atmospheric influences, we not unfrequently find that shaling occurs under the combined effects of frost and the heat to which it is exposed from the gases ejected from the chimneys of the locomotives passing under it. This fact, however, proves that it is absolutely necessary to have a lining to every tunnel, for even in one cut through granite the felspar and mica would yield to the influences above mentioned.

We will now return to the practical method of excavating a tunnel through rock. Blasting must in all cases be had recourse to, and at the present time dynamite is the explosive agent generally used; its efficiency, however, depends very much upon the proportioning of the depths and distances of the charges to the nature of the rock to be displaced. A perfectly homogeneous rock being dealt with, an uniform depth of bore hole for each charge, and an equal radial distance between the charges (or shots as the miners call them) would secure work so uniform that the trimming of the break-ups would become a trifling matter; but then it must be arranged that all the "shots" are fired at once.

In such cases as those with which we are now dealing, the matter is of no importance to the engineer-in-chief, so long as the work is completed satisfactorily; but it should be regarded as important by the contractors who carry out the work, as the use of a man (whom the late Lord Macaulay would have called a third-form boy) having an elementary knowledge of science, combined with practical experience on works, would undoubtedly increase their profits, or, to put it more in contractors' language, *diminish their losses*. The loss of human life by such neglect as occurs through carelessness in these cases we can hardly mention; although painfully "practical," it is not "commercial," as neither company nor contractor invest in the cemeteries in which those killed on their works are buried; nor can we at present call to mind any cases in which the survivors have received compensation other than that derived from public subscription.

In poling for a rock tunnel, a common practice is to pole in advance of the lining, and when the rock is of such character as can be relied upon this practice is not dangerous; but, as the general rule, we prefer the system of poling and poling boards under which the linings of the tunnels are built. This system has been so clearly shown and exemplified in the Saltwood and other tunnels, described by Mr. Timms, that it would be a work of supererogation here to repeat in detail the practical methods he has so clearly illustrated; and the more especially, as these articles are original, and, although in them we indicate the authors to whom we refer, we do not reproduce their writings.

Tunnels made through chalk formation should, as a rule, be in section of a Gothic form; as the greatest tendency to disintegration in such tunnels occurs at the soffit of the arch, and by using the form referred to—that is the Gothic—the scaling off of the chalk may, in a great measure, be prevented; whereas in the soffit of a semi-circular arch, or of a segmental arch, the chalk may scale away.

In the construction of tunnels through clay soil it is very necessary that the resident in charge of the works should know the nature of the clay soil through which the tunnel is to be driven.

The term *clay* is, in itself, a very vague one. There is the blue Oxford clay, and there is also the yellow clay; and in some districts the term shale is used, when in other districts clay would be used. The only kind of clay which obtains the name throughout the country is that which appears in the form of that clay which is usually found in the pipes of habitual smokers. In this connection, it will be interesting to our readers to know practically the weight of clay as excavated in comparison with its weight when used for work, and the more especially, as upon such knowledge must be based our methods of dealing with the foundations of all bridge stretchers. We will here give data derived from actual experience at the Leeds Sewerage Works, Knostrop, from an experiment tried June 24th, 1873. One cubic yard of clay cut from the solid ground occupied in a cart 43 cubic ft.; it weighed 1 ton 11 cwt. 2 qrs. 14 lbs.; when puddled, it weighed 1 ton 15 cwt. 0 qrs. 2 lbs., and measured 32½ cubic ft. We will add that this information has been supplied to the writer by Mr. James Craven, the resident engineer of the Leeds Sewage Works, who was charged with the superintendence of those works at the time when Mr. Alderman Tatham, now Mayor of Leeds, was Chairman of the Waterworks Committee. We will here give the local terms for the various strata in a tabulated form for the north of England :—

Local Terms.	Scientific Terms and Equivalents.
Basselt	Carbonaceous shale.
Bind	Argillaceous shale.
Black shale	Black, finely laminated, carbon shale.
Galliard	Hard, fine, close grained sandstone, or nodules of ironstone.
Crusts	Hard bands in beds of shale.
Earth	Sometimes spavin or shale.
Lifts of stone	Flaggy sandstone or thin bands.
Metal	Bind.
Rag or ragstone ...	Stone bind.
Rag shale	Shale or nodules of ironstone.
Scale	Argillaceous shale, finely laminated.
Scorff	Laminated parting in coal beds.
Spavin or seat-earth ...	Clay with stigmaria under bed of coal.
Spavin or seat-stone ...	Hard spavin.
Stone	Sandstone.
Stone bind	Arenaceous shale or sandstone.
Stone coal	Impure cannel coal.
Trub	Carbonaceous shale.
Warrell	Shale bed with thin bands of hard sandstone.

In tunnels through clay, or clayey soil, we have to provide not only for the top and side pressures, but also for the resultant upward pressure on the bottom of the work; this may be resisted by an invert, if the tunnel is of parabolic or elliptical section. This we have already explained and illustrated (page 368, vol. II.), and there is nothing further to be added to the instructions there given for this particular form of tunnel.

In some instances it is absolutely necessary to make the tunnel of a circular section, but this only occurs in soils that are practically semi-liquid.

In any ground where the soil is of a treacherous nature we prefer using a tunnel of the section (Fig. 6, page 368, vol. II.) to one in which the brickwork is continuous around, as from recent experience we have found that such lining as the latter has not withstood the pressure of the circumambient clay.

In the section to which we have referred it will be observed that there are springing stones from which the tunnel walls are started, and which also afford abutments to the invert, and this is practically a great element of strength; for the failures that have occurred in brickwork tunnels have usually been caused by the insufficient stability of the joints between the side walls and the invert of the tunnel. There is, perhaps, no matter that comes within the scope of the engineering profession that really demands a more thoroughly *practical* knowledge than that called for in the execution of tunnels. Changes of strata must be watched for in order to provide against unexpected flows of water, and also the more serious risk of a sudden fall of earth.

The drainage of the tunnels should be arranged as we have already indicated. Our remarks upon tunnelling apply equally to the construction of large culverts, and in this connection we may refer to a case of measuring up work in which the length of a culvert was questioned, for it may serve as a hint to some of our younger readers how to overcome a difficulty. The person in charge of the work had a faithful dog, and putting one end of a tape in that dog's mouth, went to the other end of the culvert and whistled for him, the dog immediately ran through the culvert, and so its length was accurately determined—the other end of the tape, of course, being held by an assistant.

It may, perhaps, be as well here to indicate that the soil beneath a tunnel should be carefully examined, as we have known of cases in which the stability of the structure has been jeopardised by the existence of old coal workings beneath it.

STATIONS.

The station arrangements on lines of railway require careful consideration, and we very often find ourselves restricted by consideration of purchase of land in addition to those other restrictions imposed upon us by the Board

of Trade. It may be as well to recapitulate here that the Board of Trade require that stations should be on gradients not exceeding 1 in 260, except where it is unavoidable. But in any case where a station cannot be constructed on the horizontal, it is absolutely imperative to provide catch points or "throw offs," so that a runaway train or truck may be prevented from causing damage.

The Board of Trade also require that the platforms be terminated by ramps; that is, inclines in place of steps, a precaution which is certainly necessary.

While writing about platforms, we may take the opportunity of expressing our own opinion in connection with their construction. We consider that in no case should there be less than 2 ft. 6 in. above rail level, and we may further suggest that if the continuous footboards of the carriages were so constructed as to overlap the edges of the platforms, such accidents as those of which we too often read of people falling between the train and platform would be obviated. We have next to consider the arrangement of the sidings in the station. These sidings we take under three classes: Sidings for goods wagons, sidings for passenger carriages, and refuge sidings. The last class of siding is that necessary for slow trains that have to be shunted to permit the passing of quick trains.

The most intricate matter in the setting out of a station is that connected with the goods department. We have to economise space in every way, and at the same time we must not make the curves of too small a radius; 600 ft. is the *least* that should be used—we prefer 800 ft; and in connection with the main line no curve should *start* therefrom with a less radius than 10 chains. When we have a station, through which the main line passes on a curve, difficulties are often encountered in satisfying the conditions above referred to, and in some instances we have found it absolutely necessary to put in curves of so short a radius as 360 ft., but round such a radius scarcely any locomotive engine of recent construction can safely pass, and we have known of several cases in which engines have run off a track laid to a radius of 400 ft.

We must also consider the position that will be most suitable for the goods warehouse, both for the delivery and transhipment—by the way, *transhipment* is rather an amusing term to be used in this connection; however, we must confine ourselves to the practical view of the case.

In setting out a goods yard there should be allowed between the roads or tracks eight feet clear, and each pair of tracks should be separated from the next by, at least, twenty feet, in order to allow of wagons or lurries being brought in for unloading or loading. Where there is plenty of room it is advisable to allow 30 feet, so that more vehicles than one can be brought in, and, moreover, they have a chance of turning.

Steep inclines are always to be avoided, if possible, on the roads leading to a goods yard; but where it is impossible to make an approach without a steep incline, the writer of these articles would advise his readers to adopt a course, which he himself adopted some twenty years back, and has found perfectly successful; it is this, instead of making the road on one continuous gradient, to break it up by short resting places on the horizontal. Such a course was pursued in the extension of the Scarborough Waterworks at Cayton Bay in 1862, in order to relieve the horses that had to work upon the road leading from the works up to the main road between Filey and Scarborough.

Sometimes we may modify the incline by giving the road one or more turns, but even then we are confronted with the danger which is that of turning a wagon heavily laden, and we think that on the whole it would be better to purchase sufficient land to make a proper approach.

We now come to consider the question of the goods warehouse. This should undoubtedly be fire-proof if combustible goods are likely to be stored in it.

The actual construction of a fire-proof building, no matter of what description or for what purpose, has always been a vexed question, and even at the present day this question is not absolutely settled. At the time when Cotton's Wharf below London Bridge was burnt, in the year 1861, the fire lasting for 23 days, and the buildings therewith connected, being supposed to be fire-proof, proved in the event how utterly futile were the attempts then made to effect the desired result.

As an example of a really fire-proof structure, we can indicate none more perfect than the goods warehouse at the City Road station of the Bradford and Thornton Railway, where the columns are encased in a cement that will resist heat, even sufficient to melt iron; the girders being also encased in a similar cement.

The old idea that iron was fire-proof has been, or should have been, exploded by this time, for neither cast nor wrought iron, *unprotected*, can resist the effect of heat. Some ten years back a goods station in Leeds caught fire, the wrought-iron girders bent, and the cast-iron columns melted under the fervent heat to which they were exposed.

Although disasters that have occurred are always worth the consideration of our young engineers, in order that they themselves may guard against their recurrence, yet it is more to the point to show how structures, such as those to which we refer, should be designed.

Following the example above cited, we should make not only the floors of the goods warehouse, but also the roof of girders, connected by cement arches, and let it be borne in mind that where these cement arches are used from girder to girder it is unnecessary to put stiffeners upon the webs; but in such cases we should not use box-girders, as the pressure of the cement arches may cause the webs to collapse sufficiently to make a crack through which fire might penetrate.

There is another point to be considered in the con-

of the wheel. We should expect him to break the flange, at least, with a fair prospect of producing a fracture in some other part of the wheel, and these blows are light as compared with the pounding the wheels receive when hacking and gouging the ends of badly constructed and misplaced guard-rails and frogs. If engineers will give their attention to the two last mentioned fixtures, the number of broken wheels and axles would be greatly diminished; but as it will be some years before these destructive agents will all be removed from the tracks, it would be well for car-builders to improve their wheels and axles with special reference to this kind of usage and the coming fast trains.

"The subject of car ventilation has been written threadbare, and some very good ventilation has been produced, but it is not an easy matter to provide for the escape of foul air, the admission of fresh air, and, at the same time, exclude dust, smoke, and cinders. A fortune awaits the inventor who will come forward with a perfect system of ventilation; but the one who will invent a receptacle for tobacco juice and expectoration will be regarded as a genuine public benefactor. The great mass of Americans travel in ordinary coaches which are usually well filled with what are popularly styled 'ladies and gentlemen.' The gentlemen (?) cover the floor with a sea of liquidity, peanut shells, fragments of lunch and all manner of filth, which the gentler sex must wade through, to the great detriment of their wearing apparel. There is hardly room on the floor for spittoons, but some nooks might be found where cuspidors could be placed, which would be far more cleanly than the present prevalent plan of using the whole floor as a spittoon and garbage box.

"Simultaneously with the addition of 10 or 15 miles an hour to the speed of passenger trains, comes longer and heavier freight trains. Motive power is being provided for handling very long trains, and, judging from what has already been done in that direction, the freight locomotive of the future will be destructive to drawing gear. The frequent failures of couplings and draw-tackle on trains that we are now handling suggest stronger attachments, even though the length and weight of trains should not be increased. The *Railroad Gazette* reports nine collisions in November last from trains breaking in two, and thirty accidents in the same month due to defects or failure of equipment. Links and pins should be made of better material, and more of it, to insure anything like safety, and when they begin to show signs of weakness should be consigned to the scrap heap.

"The next thing that presents itself for consideration, is the much invented car-coupler. We say *presents itself*, for it seems to be foremost in every inventive brain in the land. There is hardly a person of a mechanical or speculative turn of mind who cannot show from one to a dozen models of this fascinating device—not facinating to those who use them, by any means, but, on the contrary, quite the reverse. The mania pervades all classes, mercantile, agricultural, professional, and gentlemen of leisure; the cloistered dominie, even, is not an ex eption—all striving to bring forth the 'most perfect car-coupler in existence.' It is noteworthy, however, that railway mechanics are not as prolific in this class of inventions as other people, for the reason that they have a more correct and practical appreciation of the difficulties to be surmounted. The multitude of imperfect and worthless devices that have been patented has had the effect to disparage those possessing real merit. But the search for a perfect coupler is nevertheless a laudable pursuit, and it is hardly fair to sneer at the failures when the victims are really so deserving of sympathy. Let practical men, then, who have a clear perception of what is wanted, persevere in the good work until the coveted prize is won.

"The next thing is the need of a freight-train brake, which must sooner or later come into use for fast freight trains. But as the Car-Builders' Association has this matter well in hand, I will forgo any special suggestions at this time. Many lives are lost in the handling of freight cars, owing to defective ladders, hand-irons and running-boards. It would surely seem to be no difficult matter to suggest practical means to remedy this, but as the subject has recently been so fully discussed, it would be superfluous to say more until the means already proposed are carried more fully into effect. The caboose car as now constructed is not what it should be. It should be provided with end doors, with platform steps and every facility for safe ingress and egress; a cosy observatory on top for a lookout, and stairs at either end on the inside for reaching the top without climbing around the outside. Some roads have cabooses of this description, but they are exceptional and not the rule."

RAILWAY SIGNALLING.

INTERLOCKING POINTS AND SIGNALS.

(*Continued from page* 101.)

WE will now pass on to examine the construction and operation of some more recent descriptions of interlocking apparatus, and, therefore, at first will briefly refer to one of many such inventions by Mr. W. Baines, of the Railway Plant Works, Staffordshire, and as adopted at Lindal Cote Junction.

Part of the locking gear of one lever, arranged according to this gentleman's system, is illustrated at Fig. 216, (Plate CL.) of the drawings. A is an ordinary signal or point lever, formed with an enlargement at its lower end and arranged to work upon the fulcrum or shaft, B. Above B a suitable number of locking shafts, D, D^1, pass through curved slots formed in the enlargement, whereby the requisite range of motion is allowed to the levers, without interfering with these parts. On the said locking shafts are mounted sleeves or tubular rockers, E, E^1, provided with cams, e, e^1, which are caused to act at proper intervals against projections, tappets or locks fixed upon the undersides of ordinary locking bars.

Thus when the cams, e, or e^1, are prevented from being moved forward, by virtue of conflicting projections or locks bearing against them, it is rendered impossible to raise the spring-catch rod, C, from its notch in the quadrant, because it is controlled by the position of the rockers, E, E^1. By this means the locking of the levers is effected by extremely small movements of the parts, while the strain is correspondingly small.

About this time Mr. R. C. Rapier conceived a notion that, hitherto, interlocking frames were of an unnecessary complicated nature, and, therefore, set himself about to devise an apparatus of a totally different character. The idea then occurred to him to adopt sector-shaped appendages to each lever in combination with locking bar, so arranged that both the forward and back-locking could be readily effected, and, subsequently, he may be congratulated as having so well succeeded as to have been able to achieve the necessary interlocking of ten junction levers by means of only six moving pieces, and further that of eighty levers for the Great Northern Railway by twenty-seven moving parts.

He accordingly arranged all the switch and signal levers in a row, in a suitable frame, and each lever had a sector, *A*, made or formed on it and moving with it, as shown at Fig. 217 and 218. Horizontal bars, B, were provided to pass through notches in these sectors, which also had notches formed in them in suitable places. Now when the horizontal bars, B, were in such positions that the notches, C, in them coincided with any sector, that sector (and lever to which it was fixed) was capable of being moved, but when conversely they did not coincide with the same, the sector was locked and could not be moved. By arranging such notches at suitable places in the sectors and bars any number of sectors and horizontal bars were made to lock and release each other at the proper periods. Each of the switch or point levers (3 and 8) were provided with their own locking bar, and when this bar was so placed as to free the switch lever, it was capable of locking all the other levers, and which remained so locked until the switch lever was again properly secured. When the switch lever was locked in its front position some of the notches in the bar corresponded with some of the sectors, so as to set certain levers free. The locking bars were arranged to move in opposite ways for locking the levers in their forward and backward positions. The bar could not be moved in the wrong direction, as the locking notches in the segments were differently formed or arranged, while there was a corresponding difference between the two sides of the notch, C, in the bar.

It did not signify in principle whether the notches were cut in the sectors, A, or sliding bars, B, providing it was so arranged that apertures were presented where or whenever movement was necessary. The said longitudinally sliding bars were actuated by flanged pieces formed on the sectors of the lever, so as to impart the necessary alternate lateral reciprocating motion to them, but of course many other convenient means might have been adopted.

Some of the advantages considered to be attained by the inventor were :—

Small leverage and non-liability to strain, and consequent improbability of derangement, and so obvious durability.

All the locking was performed in sight of the operator, so that he could readily see by what other levers any lever about to be operated was locked.

All the apparatus was arranged entirely above the floor of the signal-box, without the large spaces before required between the quadrant plates.

At Fig. 219 is shown a side elevation of Messrs. Steven & Son's (Darlington Works, London and Glasgow) admirably simple arrangement of interlocking apparatus, as at present extensively used on the North-Eastern, South-Western, and London, Chatham Railways, &c.

A represents a point lever of ordinary design, and B, in like manner, a signal lever in its back position, both of which are mounted to work upon the fulcrum shaft, C, within notched quadrant plates, *a*, supported by light lattice or girder plates, *b*. The spring-catch rods, D, are constructed and operate in the usual manner, with the exception that usually a dead weight, *d*, is employed for forcing and maintaining them in position in lieu of a spring. Of course, any assumed advantage is open to differences of opinion, but the appearance is certainly a little clumsy and unmechanical, while in cases where the tablets or label pieces have been attached to the faces of the weights, the occasional results to the toes of the operator upon releasing the rods have been serious and most unpleasant.

However, we are pleased to note, that the labels are now attached higher up and to stationary portions of the levers, whereby such "toe crushing" propensities are avoided.

The actuation and locking is effected by notched curved bars or plates, E, connected to the levers at *e*, which operate locking pieces, F, arranged in channels formed in the curved framing at right angles to the former.

The notched curved bars, with their sliding locks and framing, may be arranged above or below the platform, G, according to convenience or requirements—the former, however, being generally preferable; but, of course, the curvatures of the bars, E, and lock frame, f, will have to be taken into consideration, and will have to vary according to the radius from the fulcrum, C.

This principle of locking is extremely old, it having been adopted by Stevens for many years past; but, nevertheless, even at the present time it would be difficult to devise a more simple and effective piece of apparatus. It is light, durable, and cheap, and simple in construction and action, while the parts can be arranged very accessibly, and capable of being most rapidly removed and replaced. Of course, it will be readily seen, that in this apparatus the actuation and locking is effected by lever upon lever or their appendages, and not by the prior movement of the spring-catch rods, as in some arrangements already referred to.

At Fig. 220 is given a diagrammatic section and plan, in order to more clearly explain the simple means by which the locking is actually effected.

E E^1 E^2 represent the curved notched actuating bars connected with the point and signal levers, P, M, and B, at *e*, respectively, and arranged to work in recesses across the curved framing, *f*, conveniently situated as before mentioned.

The curved framing is provided with a number of parallel longitudinal grooves or recesses, *g*, arranged at right angles to the aforesaid curved actuating bars.

The locks, F, F^1, consist of narrow pieces of metal, with rounded ends, capable of sliding in these longitudinal grooves, *g*, so as to be thrust at certain intervals into the notches or grooves, *i*, formed in the edges of the curved bars, E.

Thus, assuming it is desired to prevent the conflicting operation of the three levers shown in the plan, the simple arrangement could be as follows :—

When the levers are all in the forward, or normal position, both the point and main signal levers might be arranged to be free to be operated, according to whether it be desired to give the signal for the branch or main lines, but whichever lever be operated first locks the other.

Thus, according to these conditions, it will be seen that the main signal lever, M, is free to be moved over, because the lock, F, has room to slide into the notch, *i*, formed in the edge of the curved bar, E, so as to clear the maximum breadth of the bar, E^1. If such movement be effected, the point lever becomes locked, because the lock, F, fits into the notch, *i*, in the edge and cannot be forced out or displaced, because the uniform solid or unnotched edge of, E^1, is brought over the lock. The point lever being thus locked, the same conditions exist with regard to the branch signal lever, B, which is similarly prevented from being moved by means of the lock, F^1, which is incapable of being moved out of the notch, i^2, formed in E^2, and in this manner the operation of the branch points and signals is prevented when the signals are "off" for the main line.

When, however, the main signal lever, M, is returned to its normal position, and consequently the main signal put "on" or to "danger," the points are free to be moved. By pulling over the lever, P, the lock, F, is forced out of notch, *i*, and made to enter notch, i^1, formed in the edge of the bar E^1, whereby the main lever, M, is securely held in its forward position. When the point lever, P, is moved properly over to occupy its back attitude, the notch, i^3, on the other side of its curved bar, E, is brought opposite to the lock, F^1, so as to unlock or allow the branch signal lever, B, to be moved over.

In effecting this movement the lock, F^1, is forced out of the notch, i^2, in E^2, into the notch, i^3, now brought opposite to it, thereby "back-locking" the point lever, so as to prevent its return whilst the branch signal is "off."

In this manner any number of levers may be controlled, the locks being arranged according to convenience or space. Any number of curved frames, *f*, and bars, E, may be arranged one beneath each other, according to requirements or amount of locking desired to be effected.

Compact arrangement, or economy of space, is always desirable, and, therefore, where convenient or possible, special locks of peculiar construction and connection are sometimes employed, as shown at F^2, F^3, and F^4, but the principle involved remains the same throughout.

For example, it may be required to arrange a lever to interlock with its neighbour, and be further controlled or locked by another lever some distance down the frame, in

which case it will be readily seen how a lock, as represented at F^2, would meet such requirements.

The parts, 1, 2, would work in a recess between the levers, so as to lock the one whilst the other is being used, and at the same time to have one or both of them further controlled by another or other levers distantly located by means of the connection, 3, taking hold of a projection on the lock, F^3. The connecting piece, 3, runs in or over the channels in the curved framing, and terminates with a similar locking-piece working into notches formed in the edges of a curved lever bar.

F^2 shows another modification of the locking-piece, in which two levers, some distance apart, may be desired to control one lever and *vice versa*, through the intervention of the lock, 4, and connections 5 and 6.

F^4 represents a similar locking device, in which two pieces, 7 and 8, are fixed at the extremities of a thin connecting bar for effecting an interlocking action between two levers separated by intermediate ones, and in all cases the locks slide in the channels or recesses as before described, while the connections may pass over or under other locks and bars according to requirements.

At Fig. 221 is represented a method of Messrs. Stevens & Sons for readily distinguishing the functions of levers arranged in one frame, and it will be seen at a glance, to consist in making them of different heights and forms. The home signal lever is here shewn as being shorter than the point and distant signal levers, which are distinguished by differently shaped handles.

This system of distinction is, however, no longer retained, although each manufacturer generally has his own idea and views on this point as well as other matters of general arrangement.

For example, some engineers have arranged their frames in one, two, three and four rows or parts, both in straight and curved planes, with all sorts of notions as to convenience and economy of space, their adoption being chiefly continued according to individual fancies.

Of course, in constructing any such apparatus, which consists of a repetition of the same elements, the great point is to attain simplicity and lightness, consistent with strength and durability, and at the same time to, as nearly as possible, design all the parts as duplicates from the same patterns and templates, &c., and also to arrange the fitting and fixing as to be easily accessible and readily removable.

At Figs. 222 to 225 is represented Mr. Anderson's "Locking System" for railway points and signals, and as manufactured by Messrs. Courtney, Stephen & Co., of Dublin. By way of illustrating its application, the system will be briefly discussed in connection with Wooden Bridge Junction, on the Dublin, Wicklow and Wexford line.

Fig. 222 represents a sectional plan of the signal box, above which the semaphores and spectacles are carried by posts in the usual manner, and are therefore omitted from the drawing. It will be observed that the lines, or metals shown, are purely diagrammatic, and drawn to a smaller scale than the other parts.

Figs. 224 and 225 represents enlarged details of the locking gear.

A, B, C, and D, Fig. 222, are short levers arranged on the said posts for working the signals. The left hand post, P, is for the main line, and the right hand post, P^1, for the branch line respectively to Shillelagh. F and H are the levers for operating the main line distant signals; E and L, similarly the distant signals of the tramway which runs from the Avoca mines to Arklow. G is a lever for actuating the branch line distant signal; K, the station tramway signal; and the remaining lever, *M*, works the points. Each of these levers, except the ones attached to the main signal posts, pass through the floor to the cast-iron beam, R, which crosses the house at right angles to the levers—the ends of the said beam being built into the wall of the house. Suitable double jaws are cast on it, between which the fulcrums of the levers are secured by means of a pin passing through them. These levers move in wrought-iron quadrants, fastened either to the floor or to a cast-iron frame. The levers are secured in their extreme positions by spring-catch rods or bolts attached to the back of each, which work into notches cut in the quadrants. The levers are connected with the distant signals by means of galvanized, stranded, or twisted iron wire, in the usual manner, which passes over pulleys placed about 40 ft. asunder; and to the switches by gun barrel tubing working through ground brackets or supports (with two rollers in each, one above, and one below the tube), placed about 14 ft. asunder. The principle of the locking apparatus has been borrowed from that beautiful machine the "Jacquard" loom, and consists in a "selecting" bar and lever, together with a couple of guide bars secured to the underside of the floor, by means of brackets. O is the selecting bar, S the lever actuating the same, while M and N are the guiding bars. To each signal and point lever is attached a locking rod, W, which reaches from the lever to the guide bar, M or N, determined by its position in the box; the guide bar being suitably cut to receive it. When all the signals are at "danger," the point of each "locking rod" is thus left protruding about a quarter of an inch on the inside of the guide bar, but not in contact with the selecting bar, which can be moved freely in a horizontal direction by means of the lever. S.

The aforesaid "selecting bar" is similarly perforated to the guiding bars above referred to.

Now, assume it is required to let a train proceed from Dublin to Shillelagh, which necessitates the establishment of communication between the main and branch lines, the operator then pulls over his proper point lever (notified by a brass label thereon) so as to bring the solid part of the

"selecting bar" opposite the locking rods of the conflicting signal levers, and at the same time causes certain apertures therein to be brought opposite the levers to be liberated.

The levers, when thus set free, have to be moved in proper sequence or order, by means of the holes in the "selecting bar" being cut a little lower than those in the guiding bars, so that the former has to be slightly raised before certain liberations are allowed, and which is effected by forming the signal-locking rods with tapering terminations as shown. To accomplish the back-locking, a notch is cut on the upper side of the point-locking rod immediately under the guide bar, N, while the locking rod of the station signal, C, is also tapered. So on the lowering of the station signal the selecting bar is again raised, when the notch in the point-locking rod grasps the guide bar, N, and thus effectually locks the point lever while the signal is lowered.

Thus by simply shifting or altering the position of the selecting bar any number of necessary combinations may be effected without the addition of further machinery.

If the number of levers in a box is very large it is in most cases desirable to divide the selecting bar in the middle, and to have two selecting levers—one at each end of the frame, or arranged together in the centre.

This type of apparatus is peculiarly original, although not extensively used, and unlike others in that the lever making the selection has no other functions to perform, and is not, therefore, liable to be strained or thrown out of adjustment when actuating the points or signals. Further, the stroke of the lever is not limited—a very unique advantage in working distant signals, where not only the lengths traversed, but the portion of the quadrant over which the traverse takes place, varies with changes of temperature, or stretching of wires, &c. Again, it is easy to change the combinations among the levers—a point of some importance on main lines, where the Government inspectors very frequently order changes to be made in the mode of working junctions, which in this apparatus can be effected in a few hours by simply cutting the necessary holes in the selecting bar. At Wooden Bridge Junction (the example given), the distant signal, G, on the branch line is located so far round the curve as not to be visible from the box, so that it is necessary to put a "repeater," G^1; or an auxiliary distant signal.

Fig. 226 (Plate CLI.) represents a perspective elevation of Mr. Wm. Smith's interlocking apparatus, as manufactured at the Railway Signaling Works, Manchester. The principle involved is to accomplish the locking prior to the movement of the levers, by means of small treadles, A, mounted and suitably arranged and connected in front of them. The treadles are attached to sliding bars extending right across the frame, on which small catches or projections are formed. On a treadle being depressed by the foot of the operator, the respective sliding bar and catches are caused to pass under the treadles of conflicting levers, so as to prevent their being depressed and releasing a lever at variance to the safe condition of affairs. It will therefore be understood how that no lever can be pulled over until the relative treadle is pressed down, and the whole of the locking actuated and controlled by such means.

According to this method, the actuation and locking is certainly effected in a simple manner, without unnecessary complication in the construction of the apparatus.

We have already briefly referred to Mr. Saxby's invention of the "spring-catch rod actuation," as at first constructed and arranged, and which consisted of a diagonal or angular actuating piece, which was found by experience to so cut and wear the contiguous parts as to afford little durability and reliance.

At Fig. 227 is shown Mr. Saxby's improvements of 1870 to obviate the above defects. This consisted in providing a slotted rocker or oscillating piece, *A*, mounted on the pin, *a*, which served for the combined purposes of holding the lever in position, and also operating the locking mechanism. An ingenious device still effectually retained in the above named gentleman's present frames or apparatus.

Upon referring to the drawing it will be seen that the curved slotted rocker, *A*, mounted on the fulcrum, *a*, receives a cross piece or projection, *b*, formed on the end of the spring-catch rod, B, by which it obtains its oscillating motion. One end of the rocker is connected to the actuating locking rod, C, through the intervention of the lever, D, (or its equivalent), by which the vibrating motion of the former is imparted to operate the locking mechanism, which may be of any suitable desired kind.

Figs. 228 to 230 inclusive, represent Mr. John Imray's interlocking apparatus of 1872. This invention incorporates a very ingenious principle, the patent for which was subsequently purchased by the firm of Messrs. Saxby & Farmer.

As a means of locking it is perhaps as simple and effectual as any yet devised, in fact it still forms an important element in one of the best types of interlocking frames at present in use. It consists of hollow or tubular rocking shafts, E, mounted in convenient bearings, and formed with slots, *e*, through them, having enlargements, e^1 and e^2, at the ends, as shown, in which the point and signal levers, L, are caused to travel when operated. A section of the hollow rocking shaft is shown at Fig. 229, by which it will be seen that a recess, *f*, is provided for the reception of a projecting cross-piece, F, carried by the spring-catch rod, C, which works behind the lever, L, through the slot, *e*, in the ordinary manner. It will now be really understood that upon raising the catch-rod a slight circular motion is imparted to the rocking spindle, E —ingeniously utilised to effect the required interlocking

action. At one end of the shafts circular-locking pieces, E^1, are annexed, which are of the section represented at Fig. 230.

Thus the revolution of the shaft is caused to bring certain parts in contact with locks or stops, g, g^1, carried by bar, G, to which is imparted a rectilinear reciprocating motion. Thus assuming 1, 2 and, 3 to represent transverse sections, through such circular or curved locks, E^1, of a main point, and branch lever rocking shaft respectively, the arrangement and operation of them would be as follows :—

The point lever-locking piece, 2, is in communication with the bar, G, through the intervention of the pin, p, carried by the latter and fitting into a recess cut in the former. So that by moving the catch-rod of the point lever a revolving motion is imparted to the rocking shaft, 2, which communicates its motion to the bar, G, so as to bring the stop or projection, g, under the curved locking piece; h, thus preventing the rocking shaft, 1, of the main signal lever from being moved.

In this manner any conflicting lever can be prevented from being moved along the slots, e, as the spring-catch rod has first to move the shaft into a position for the shoulders of the enlargments, e^1 or e^2, to clear the lever desired to be operated.

The back-locking is in like manner and as simply effected, because by lowering or releasing the catch-rod, the rocking shaft is again moved, so as to bring the shoulder of the enlarged slot at the opposite end behind the lever.

Figs. 231, 232 and 233, represent views of Mr. J. Bailey's interlocking apparatus, as chiefly used upon some of the Irish Railways.

It consists of a number of flat bars moving in a guide trough, seated on and fixed to brackets cast on the lever frame, as shown at A, in Fig. 231. These guide troughs and running bars are notched out at proper places to admit the horizontal bars, B, to rest in them. On the under side of these bars is fixed an angle bar or incline plane, shown in detail at Fig. 233, which actuates the running "lock bar." when the lever, to which it is attached, is pulled over. It will be at once seen that by the movement of any one of these "running bars," any or all the levers can be most effectually locked or released at will. Each lever in the locking frame is provided with a horizontal bar, B, and locking rod, which is in no way connected to, or influenced by, the other levers or bars—in fact, each lever has power to "lock" or "unlock" all the others, and is in no way affected by them. The *locking* or *releasing* also takes place on the *slightest movement* of its lever, which of course is most desirable.

On referring to the plan, Fig. 232, it will be seen that No. 1 lever, in its normal position, is locked by No. 3, so that 3 releases 1, and 1 *back*-locks 3. In the same manner 2 is locked in its normal position by 4, and 4 further, not only releases 2, but at the same time locks 3, while 2 on being pulled over *back*-locks 4.

Figs. 234 to 236 inclusive, illustrate Messrs. McKenzie & Holland's apparatus, invented in 1873, and still extensively employed on various railways throughout the United Kingdom. It is an improvement upon their type of apparatus, patented in 1866, already illustrated and briefly described. (Figs. 200, 201, Plate CXLVI.)

According to that arrangement it will be remembered that the locking gear was placed behind the levers, to be controlled and worked upon the same axis as the cams on which the levers acted.

In their present arrangement now before our notice, the locks are situated in front of the levers, and are mounted upon separate axes, by which a more close and secure locking action is achieved. The locks hereafter explained are not self-acting, and are maintained in balance by suitable counterweights, so as to reduce the weight upon the levers.

The locking mechanism being secured to their axes by semi-circular removable bearings, great facility is obtained for removing any portion of the apparatus, while all the parts are arranged accessible for repairs or adjustment. At Fig. 234 the point lever, A, which is of ordinary construction, is shown as locked in its normal position by the stud, C, (fixed to the lever), being engaged at the one end of the slotted cam piece, B, which is mounted at b.

When the conflicting levers are in their inoperative position, the stud, C, on the point lever is free to be moved along the slot, which imparts motion to the connections, E and F, so as to operate the locks, e and f, and thus bring them into their proper position to lock the levers desired to be secured.

The signal lever, G (Fig. 235), provided with the stop or stud, g, is shown free to be moved clear of the raised lock, e. On pulling the lever forward, the stud, g, prevents the lock, e, being depressed beyond a certain extent, but when the conflicting point lever is moved, e is caused to descend so as to engage with the aforesaid stud.

At Fig. 236 the branch signal lever, H, is represented as being locked by the engagement of the shoulder of the lock, f, with the stud or stop, h, upon the former, while the point lever is supposed to be in its normal position. Thus it will be seen that according to the condition represented in the drawings, the point lever, A, is secured by the stud, C ; the signal lever, H, similarly locked by that of h ; while the signal lever, G, is liberated and free to be moved forward. The rocking shafts, S, carrying the locks are operated by the point lever connections, as shown.

About the best examples of the application of this type of apparatus may be seen at Liverpool Street G. E. Terminus, where there are 100 levers in one frame, and at York Station, N. E. R.; 370 levers controlled in the above manner being employed to work this latter station, which is certainly one of the largest and finest in the world.

Fig. 237 represents an arrangement of apparatus, by the same manufacturers, for effecting the interlocking of levers placed at a distance, as is frequently required in working siding points some way off from the box. For this purpose a movable quadrant, O, is provided, mounted on the fulcrum, O^1, and connected with the signal lever, P, by the rod, *g*. When the movable and fixed quadrants, O and N, respectively are parallel, the lever, M, may be used to work the points. But when it has been moved, it is subsequently secured in such position by a pin or bolt, so as to prevent a distant signalman from raising the quadrant, O, and so operate a conflicting signal while the distant point lever is being used.

Fig. 238 simply represents Mr. Saxby's method of 1874 for actuating the locking mechanism through the intervention of a slotted plate, I, connected with the levers. Projections or rollers are provided at the ends of the actuating rods, C, which are caused to travel in the slots, i, as the levers are moved to and fro, by which a vertical reciprocating motion is imparted to the former. The slots in the plates may be straight or inclined, according to requirements.

At Fig. 239 is illustrated another locking device of Mr. Saxby's, brought out in the same year, and it will be seen at a glance to incorporate part of Mr. J. Imray's principle before referred to. It consists in the employment of rocking shafts, R (worked by cranked connections), having flattened locking part, $r\ r^1$, working in combination with sliding bars, A, B, provided with stops, *a*, *b*, fixed thereon. Each of these rocking shafts is moved from one of the levers or from the rockers already described. The flattened parts, $r\ r^1$, are thus caused to move the bars so as to affect the necessary locking.

Fig. 240 represents an interlocking apparatus invented and manufactured by Messrs. Tweedy & Co, of Carlisle, in which the simple arrangement of the working parts is worthy of attention.

By way of example, it may be assumed that the locking required in a set of 8 levers, (in which only the first and third are shewn), to be as follows :—

On lever No. 1 is fixed stud a^1, which on the lever being pulled over gives motion to the link b^1. And this through the fulcrum c^1, and connecting rod d^1, and the arm e^1, revolves the shaft f^1, running longitudinally in front of the frame.

On the same shaft and opposite No. 3 lever is fixed an arm g^3, which catches a stud h^3, fixed on the locking bolt of No. 3 lever, and lifts it up into the slot in the under side of the segment in which the lever works, and thus No. 3 lever becomes interlocked.

The action of back-locking No. 2 lever (not shown) is as follows.—Presuming that No. 2 lever has already been pulled back, if No. 1 lever be moved, the motion will be conveyed through links b^1 and k^1, connecting rod l^1, and arm m^1, to the shaft o^1. And this, by an arm n^1, opposite No. 2 lever, and a stud h^2, will raise the locking bolt of lever No. 2 into the slot of the segment, thereby back-locking it.

Lever No. 1 is interlocked by No. 3, which has been pulled over, and, through a similar set of levers and links to those already described, lifted the locking bolt by the stud h^1, into the slot of the segment, thus preventing No. 1 lever from being operated.

(To be continued.)

LIGHT RAILWAYS.—BELPAIRE'S STEAM CARRIAGE.

BOILER. — As will be seen from the figures, Plate CXLVIII., this boiler is constructed to obtain with a short length, a large heating surface and capacity for steam ; for this purpose the body of the boiler is formed of two superposed cylindrical shells, strengthened horizontally at the weak point of their junction by a double row of tie-rods. The tube-plate of the smoke-box is strengthened by a transverse plate and by the rounded form of its upper part. The gases after leaving the smoke-box travel about two-thirds the length of the boiler before passing to the chimney.

The principal particulars of the boiler are the following :

Grate area	G =	5·23 sq. ft.
Heating surface	f =	26·29 ,,
Area of tubes...	t =	206·9 ,,
Total	s = f + t =	232·38 ,,

$$\frac{s}{G} = 45{\cdot}33\ ;\ \frac{f}{G} = 5{\cdot}122\ ;\ \frac{s}{t} = 1{\cdot}128;\ \frac{s}{f} = 8{\cdot}87$$

Volume of Water	E =	21·18 c. ft.
Volume of Steam	V =	17·65 c. ft.

$$\frac{E}{V} = 1{\cdot}12$$

Pressure = 10 atmospheres

The fire-box is of copper, the tubes of brass, and the rest of the boiler of iron. The grate formed to burn small fuel is composed of bars of a thickness of ·31 in., the spaces between them being ·07 in. Notwithstanding its bracing, and the exceptional care necessary in its construction, this form of boiler offers a great resistance to the steam pressure ; in several cases the junction of the cylindrical shells is strengthened by means of plates of a thickness of 1·17 in., as shown at Fig. A, Plate CXLIX.

M. Evrard, director of the Belgium Company for the construction of these engines, proposes to replace this boiler by the type illustrated on Plate CXLIX., which is quite as strong, furnishes steam as dry, and is of a construction complying with the rules for the resistance of the materials. This form is being adapted for the carriages now being constructed.

(*Continued from page* 71.)

TABLE I.—(*continued.*)

1	2	3	4	5	6	7	8	9	10	11	12	13
No. of Piece.	Makers.	Application.	Year made.	Modulus of Elasticity. Kg. per sq. mm.	Limit of Elasticity. Kg. per sq. cm.	Breaking strength Kg. per sq. cm.	Contraction of Area per cent.	Elongation in 25 cm. (10 in.) per cent.	Analysis. Carbon per cent.	Sulph. per cent.	Phosph. per cent.	Remarks.
107b	Quint, Trier.	Flats for heavy smith work 105by20	1876	2 139 000	1300	3450	10	5.7				Flat piece. Half fibre, with large dirty patch; half coarse crystal. Brittle iron.
108a	ditto	ditto 205by14	1876	2 119 000	1690	3500	18	6.0				Ditto. Rough dull fibre, with some crystalline spots.
108b	ditto	ditto	1876	1 993 000	1960	3720	22	9.0				Ditto. Fine fibre in layers, with some crystalline spots.
145a	Reschitza Iron & Steel Works.	Tools.	—	2 282 000	930	3280	53	—				Fibrous, honeycombed, with scattered crystals.
145b	ditto	ditto	—	2 233 000	1180	3300	51	23.4				As last.
147a	ditto	Flats for tools 70 by 14	—	1 982 000	930	3580	44	—				Flat piece. Oblique fracture, very fine fibre.
147b	ditto	ditto	—	2 113 000	1110	3460	46	22.1				Ditto. Fine fibre, with porous look.
148a	ditto	ditto 29 by 7½	—	—	—	3260	52	17.8				Ditto. Fne fibre.
148b	ditto	ditto	—	—	—	3240	57	20.2				Ditto, ditto.
149a	ditto	Flats for raily. spikes 19by11	—	—	—	3800	50	—				Ditto, ditto.
149b	ditto	ditto	—	—	—	3570	54	—				Ditto, ditto.
150a	ditto	ditto 13by14	—	—	—	2990	59	15.3				Ditto, ditto.
150b	ditto	ditto	—	—	—	2980	59	12.3		0.00	0 008	Ditto, ditto. Trace of arsenic.
179a	Royal Hungarian Iron Works, Rhonitz.	Squares.	1877	—	—	3360	41	17.5				Fine fibre, dark and bright mixed irregularly; honeycomb, and some small crystals; outside cracked.
179b	ditto	ditto	1877	—	—	3260	35	15.4				Half fibre, half crystal; outside cracked.
180a	ditto	Rounds.	1877	—	—	3540	36	22.4				Fine fibre, with honeycomb and some crystalline spots; outside rough and cracked over a broad band.
180b	ditto	ditto	1877	—	—	3470	27	16.6				All this series good smiths' iron. Fracture like last, with peculiar zigzag cracks; outside much cracked.
163a	Ozd Iron Works.	Rounds for engine and wagon work.	1876	2 169 000	1720	3990	33	—				Fibrous in thick flat layers, with some crystalline spots.
163b	ditto	ditto	1876	2 209 000	2020	4040	43	24.3				Dark grey fibre, irregular layers, with some open cracks between; some small lengthwise cracks outside.
164a	ditto	Squares for engine work.	1876	2 254 000	1780	4020	33	—				Very fine bright grey fibre, with small yellowish spot; outside cracked close to fracture.
164b	ditto	ditto	1876	2 180 000	1940	3920	29	20.8		0.01	0.051	Bright and dark grey fibre, irregular, some yellowish spots; irregular cracks; much arsenic.
165a	ditto	Flats for engine work, 52 by 25	1875	2 105 000	2310 ?	3970	31	22.3				Flat piece. Short fibre, dark and bright mixed, in layers, with some cracks.
165b	ditto	ditto	1875	1 968 000	1350	3980	28	22.7				Ditto. As last.
166a	ditto	ditto 40by21	1876	2 316 000	1000	3870	31	19.4				Ditto. Fine fibre, in layers, dark and bright.
166b	ditto	ditto	1876	2 254 000	1220	3980	31	22.1				Ditto. As last.
167a	ditto	ditto 39by13	1876	2 149 000	2900	4120	26	11.9				Ditto. Very bright and dark grey, in layers.
167b	ditto	ditto	1876	2 050 000	1480	3960	38	18.2				Ditto. Short fibre of confused structure; some crystalline spots.
121a	Köhrig Bros., Brunswick.	Girder-iron.	1863	—	—	3830	20	9 2				Ditto. Short fibre, in fine layers.

TABLE I.—(*continued.*)

1	2	3	4	5	6	7	8	9	10	11	12	13
No. of Piece.	Makers.	Application.	Year made.	Modulus of Elasticity. Kg per sq. mm.	Limit of Elasticity. Kg. per sq. cm.	Breaking strength. Kg. per sq. cm.	Contraction of Area per cent.	Elongation in 25 cm. (10 in.) per cent.	Analysis. Carbon per cent.	Sulphur per cent.	Phosph. per cent.	Remarks.
121b	Röhrig Bros., Brunswick.	Girder-iron.	1863	—	—	3770	20	10.8				Flat piece. Short fibres, clear and dark in layers.
123a	Sieg-Rheinische Mine & Forge Co.	Engine work.	1875	2 177 000	1460	3910	35					Fibrous, irregular mixture of clear and dark scattered crystalline points. Cracked outside.
123b	ditto	ditto	1875	2 155 000	1850	4000	34	23.3		0.05	0.284	Fine fibres, with spots of crystal and grain, slightly cracked outside. Some arsenic.
113a	Stumm, Neunkirchen.	Rounds for heavy smith work.	1877	—	—	3750	38	23.6				Fibrous, in dark layers, with scattered crystalline points.
113b	ditto	ditto	1877	—	—	3780	36	23.9				Similar, with gaping cracks.
114a	ditto	ditto	1877	—	—	3550	33	20.0				As above, much cracked outside.
114b	ditto	ditto	1877	—	—	3620	33	20.5				As above, with one large piece of coarse crystal. Outside much cracked.
91a	ditto	Flats for heavy smith work, 49 by 16	1877	—	—	3720	13	9.9				Flat piece. Rather short, dull fibre, with unwelded places.
91b	ditto	ditto	1877	—	—	3640	14	8.2				Ditto. Fibre in fine layers, with crystalline spots.
97a	ditto	ditto, 49 by 19	1877	—	—	3950	21	14.2				Ditto. Fibrous, with large crystalline spots.
97b	ditto	ditto	1877	—	—	3740	22	14.6				Ditto. As above, large cracks; outside cracked.
98a	ditto	ditto, 65 by 13	1877	—	—	3260	10	4.4				Ditto. Fibre in fine layers, with crystalline spots.
98b	ditto	ditto	1877	—	—	3570	16	7.4				Ditto. As above, very short fibre.
100a	ditto	ditto, 77 by 23	1877	—	—	3470	16	10.6				Ditto. Short fibre, with large crystalline spots.
100b	ditto	ditto	1877	—	—	3500	14	10.4				Ditto. Similar.
101a	ditto	ditto, 60 by 22	1877	—	—	3800	19	13.8				Ditto. Rather short fibre, with crystalline spots; outside slightly cracked.
101b	ditto	ditto	1877	—	—	3740	18	10.8				Ditto. As above, but with only one small crystalline spot.
102a	ditto	ditto, 77 by 19	1877	2 004 000	1150	3630	20					Ditto. Dark grey fibre, rather short, in fine layers. Fracture influenced by stamping letters.
102b	ditto	ditto	1877	2 015 000	1270	3860	20	12.7		0.06	0.305	Ditto. Fine layers of fibre, with scattered crystalline spots. Trace of arsenic.
103a	ditto	ditto, 90 by 12	1877	2 089 000	1480	3350	17	6.3				Ditto. Fine short fibre, with small crystalline streaks.
103b	ditto	ditto	1877	2 014 000	1580	3630	18	11.1				Ditto. Fine short fibre, with some small crystalline spots.
104a	ditto	ditto, 140 by 9	1877	—	—	3370	18	7.1				Ditto. Fibrous, in fine layers.
104b	ditto	ditto	1877	—	—	3350	18	6.3				Ditto. As last, with some crystalline spots.
105a	ditto	ditto, 88 by 18	1877	—	—	3570	17	13.0				Ditto. Short dull fibre, with scattered crystalline spots. Outside flaky.
105b	ditto	ditto	1877	—	—	3360	12	7.9				Ditto. Large crystalline spots, and unwelded layers.
109a	ditto	ditto 275 by 20	1877	1 949 000	1475	3725	15	10.4				Ditto. Short dark fibre, with large crystalline spots, and a flaw right through.
119b	ditto	ditto	1877	1 998 000	1360	3740	13	10.4				As last.
110a	ditto	ditto, 80 by 30	1877	—	—	3660	25	18.2				Ditto. Short fibre, with several large crystalline spots. One end very bad.
110b	ditto	ditto	1877	1 981 000	1370	3650		12.2				Ditto. Only about one-third fibrous, rest crystalline.

1	2	3	4	5	6	7	8	9	10	11	12	13
									Analysis.			
No. of Piece.	Makers.	Application.	Year made.	Modulus of Elasticity Kg. per sq. mm.	Limit of Elasticity. Kg. per sq. cm.	Breaking strength. Kg. per sq. cm.	Contraction of Area per cent.	Elongation in 25 cm. (10 in.) per cent.	Carbon per cent.	Sulphur per cent	Phosph. per cent	Remarks.
171	Sucha, Braniki Iron Works, Galicia.	Rounds for loco. building, 42 mm.	1877	2 223 000	1690	4070	17					Showed cracks lengthwise when worked at red heat; very good at welding heat. Fracture half crystalline, one-third grain, rest fibre.
172	ditto	ditto, 50 mm.	1877	2 168 000	1620	3890	14	11.9				As above. Grain and crystal irregularly mixed. One large fibrous place. Deep and wide cross cracks outside.
173	ditto	Charcoal rounds for locos., 42mm.	1877	2 196 000	1620	4140	37	21.3				As above. Fine grain, clear grey, in strong layers; cracks outside near fracture.
174	ditto	ditto, 45 mm.	1877	2 204 000	1630	3360	47	25.4				As above. Fine fibre, clear and dark, mixed irregularly, with cracks. Outside cracks lengthwise and crosswise.
175	ditto	Charcoal flats for locos., 80by20 mm.	1877	2 308 000	1670	3870	31	19.8		0.01	10.09	Flat test piece. Good in working. Fibre in layers, light and dark, irregular; small crystalline spots. Slight arsenic.
176	ditto	ditto, 40 by 13 mm.	1877	2 108 000	1920	—	37	17.8				Ditto, ditto. Very fine fibre, part very short; outside, several large and deep flakes.
177	ditto	ditto, 40 by 20 mm.	1877	2 062 000	1280	4090	33	13.7				Ditto, ditto. Fine fibre, light and dark, irregularly mixed, with clefts.
178	ditto	ditto, 27 by 13 mm.	1877	2 106 000	1530	4250	39	16.3				Ditto, ditto. Fine fibre, half dark, half light grey; gaping cleft between the two.
12a	Royal Wurtemb. Mining Office, Wasseralfingen.	Rounds for draw bars	1876	2 072 000	1930	3720	36		0.05	0.304		Fine dark grey fibre, with some glittering grains.
12b	ditto	ditto	1876	2 184 000	2360	3900	41	27.5				Fine fibre, with some glittering points; outside rough and somewhat cracked.
75a	ditto	Rounds for couplings	1877	—	—	3620	37	24.0				Fine fibre, with scattered glittering points, and one crack.
75b	ditto	ditto	1877	—	—	3620	46	23.2				Similar.
76a	ditto	Flats for nuts, 25 by 14 mm.	1877	—	—	3780	37	17.1				Flat test piece. Fine fibre, but short.
76b	ditto	ditto	1877	—	—	3870	36	14.3				Ditto. As above.
5a	ditto	Flats for ordinary use, 50 by 16 mm.	1876	2 036 000	1410	3450	28			0.03		Ditto. Soft in working. Grey fibre, in fine layers. Broke at nick.
5b	ditto	ditto	1876	1 909 000	1420	3430	39		0.11			Ditto, ditto. As last, with broad unwelded layer.
6a	ditto	ditto, 40 by 11 mm.	1876	2 096 000	1430	3740	41					Ditto, ditto. Fine fibre, light and dark grey, irregularly mixed.
6b	ditto	ditto	1876	2 064 000	1240	3640	39	21.6				Ditto, ditto. As last.
7a	ditto	ditto, 33.5 by 14 mm.	1876	2 093 000	1340	3570	42		0.08			Ditto, ditto. Very fine fibre, uniform dark grey.
7b	ditto	ditto	1876	2 137 000	1100	3690	40	16.3				Ditto, ditto. Very fine short fibre, in strong layers.
8a	ditto	ditto, 34 by 8.5 mm.	1876	1 888 000	1375	3650	29					Ditto. ditto. Very fine fibre, uniform dark grey. Broke at a flaw.
8b	ditto	ditto	1876	2 264 000	1220	3530	36	15.4				Ditto, ditto. Very fine fibre.
9a	ditto	ditto, 28 by 12 mm.	1876	1 900 000	1700	3850	35		0.09	0.08	0.298	Ditto, ditto. Very fine fibre. Broke at a nick. Trace of arsenic.
9b	ditto	ditto	1876	1 904 000	1650	3680	34	15.7				Ditto, ditto. Very fine short fibre, irregularly cracked.
10a	ditto	ditto, 25 by 15 mm.	1876	1 956 000	2040	3830	37					Ditto, ditto. Very fine fibre, with some crystalline spots.
10b	ditto	ditto	1876	2 045 000	1750	3790	36	17.6				Ditto, ditto. Very fine fibre.
11a	ditto	ditto, 19 by 12 mm.	1876	1 910 000	1470	3820	42			0.07		Ditto, ditto. Very fine fibre, with peculiar white spot.

(*To be continued*).

SIEMENS' GONG SIGNALS.

MESSRS. SIEMENS BROTHERS & CO. have devoted considerable attention to Railway Signalling, and we extract from their pamphlet on Gong Signalling Apparatus the following particulars of their special inventions to meet the requirements of railway traffic upon lines which do not require a block system :—

Fig. 1 is a vertical section of a small house or hut which serves as a shelter for the gate-keeper at a level crossing or other place where a gong is required. The hut contains clockwork while the gong is erected above the roof. The clockwork is enclosed in a protecting case, and the ends of the levers, L L_1, are connected, as shown, with the hammers which strike the bells, by means of cords passing through the roof. The electrical connections with the line-wire and earth are indicated by dotted lines.

Fig. 1.

Other forms of gong alarums are supplied to suit any particular purpose; they differ from one another principally as regards the number and size of gongs and the mode of attachment to walls and supports.

The gongs, either single or double, are about 24 in. in diameter, and the clockwork apparatus is of suitable dimensions and construction for the kind of gong it is intended to work.

The adoption of two distinct circuits between stations is recommended, one for the telegraph service and the other for the alarum signals. Should a more economical arrangement be desired, however, one circuit can be made to suffice. In this case, with the older form of instruments, the telegraphing current passes through all the electro-magnets of the clockwork apparatus, and its strength is so regulated that it cannot attract the armatures, but has power enough to work the relays at each station. A stronger current for releasing the clockwork apparatus and setting the gong-hammers in motion is sent into line by means of a key.

The use of a key enables the sender to transmit a variety of signals, which are made by one, two, or more strokes on the bells. A code of signals is generally agreed upon, such signals being simple combinations of one, two, or more groups of loud bell strokes, and may mean "up train," "down train," "stop all trains," "twelve o'clock," &c.

Gong signals can be heard distinctly at a distance of 500 yards from the gate-keeper's hut, and cannot fail to draw his attention to the approach of a train. The gates of the road-crossing must then be closed (thus opening the line for the passage of the train), and the optical signals, points, &c., placed in proper position. These gong-signals are of special service at night-time and in foggy weather, when optical signals, such as semaphores, discs, &c., cannot be relied upon.

In the new form of apparatus, magneto-inductors have been adopted for signalling purposes, because they remove the defects of galvanic batteries. They consist of a series of twelve permanent magnets, between which a Siemens' armature revolves when the handle of the inductor is turned. (See Fig. 2.) Each complete revolution of the armature produces two currents in opposite directions in a coil of insulated wire forming part of the cylindrical armature. One revolution of the handle causes the armature to revolve thirteen times, and consequently twenty-six currents, alternately positive and negative, are generated in the insulated wire coil during this time, and are sent into the line wire. The apparatus has two keys, or plungers, I and II, one for the up and the other for the down line wire, so that, by means

of one magneto-inductor, currents can be sent in either direction by pressing down key I or II and turning the handle at the same time. A protecting case covers the inductor, with the exception of the handle and the two keys. On the apparatus-board are brass terminals for the gong-wires, and earth connection. When a gong signal has to be given, the operator at the station presses down the corresponding plunger, turns the handle of the inductor, and sends a number of alternate or reversed

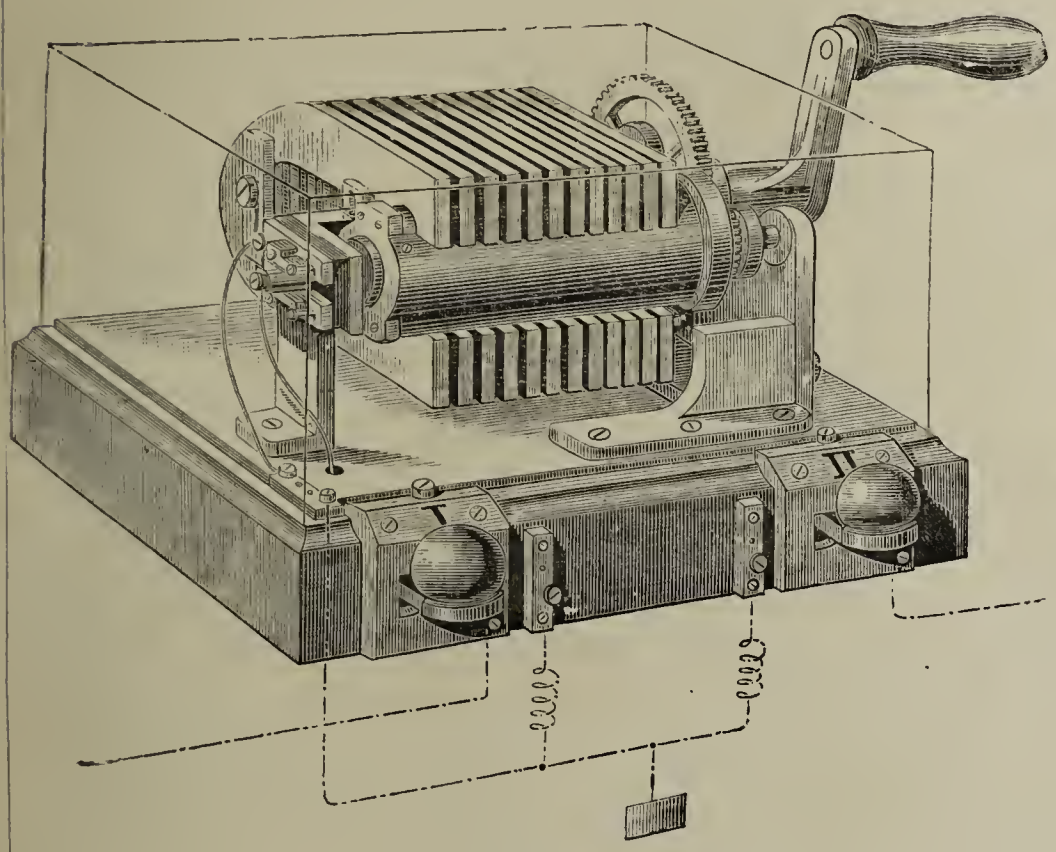

Fig. 2.

currents into the line. The clockwork of all the alarum apparatus between his station and the one in advance is thereby simultaneously released.

Inductors of this description are used in great numbers on railway lines; their advantages are as follows:—

(*a*) The inductor gives currents of constant strength; and the adjustment of the gong alarums, when once made to suit these currents, does not require alteration. The reversed currents of the inductor are not affected in such a perceptible degree by leakage of the line and by atmospheric electricity as are the currents of galvanic batteries.

(*b*) The currents generated by the inductor are more powerful than a battery current, and therefore act with greater energy upon the armature. As this can, in consequence, be more firmly adjusted, the virbration of heavy trains cannot move it and so start the clockwork.

(*c*) The inductor occupies very little space; it can easily be put up, and no trouble or expense is subsequently incurred for maintenance and cleaning, such as batteries continually require.

The improved gong-alarums are constructed so as to be worked by the alternate or reversed currents from the magneto-inductor described above. In these new gongs the armature carries an escapement, which works into a toothed segment attached to the end of a lever. When a number of positive and negative currents pass through the electro-magnet, the escapement oscillates and allows the segment to rise tooth by tooth, the lever is raised at the same time and releases the clockwork, thereby putting in action the gong-hammers.

Fig. 3.

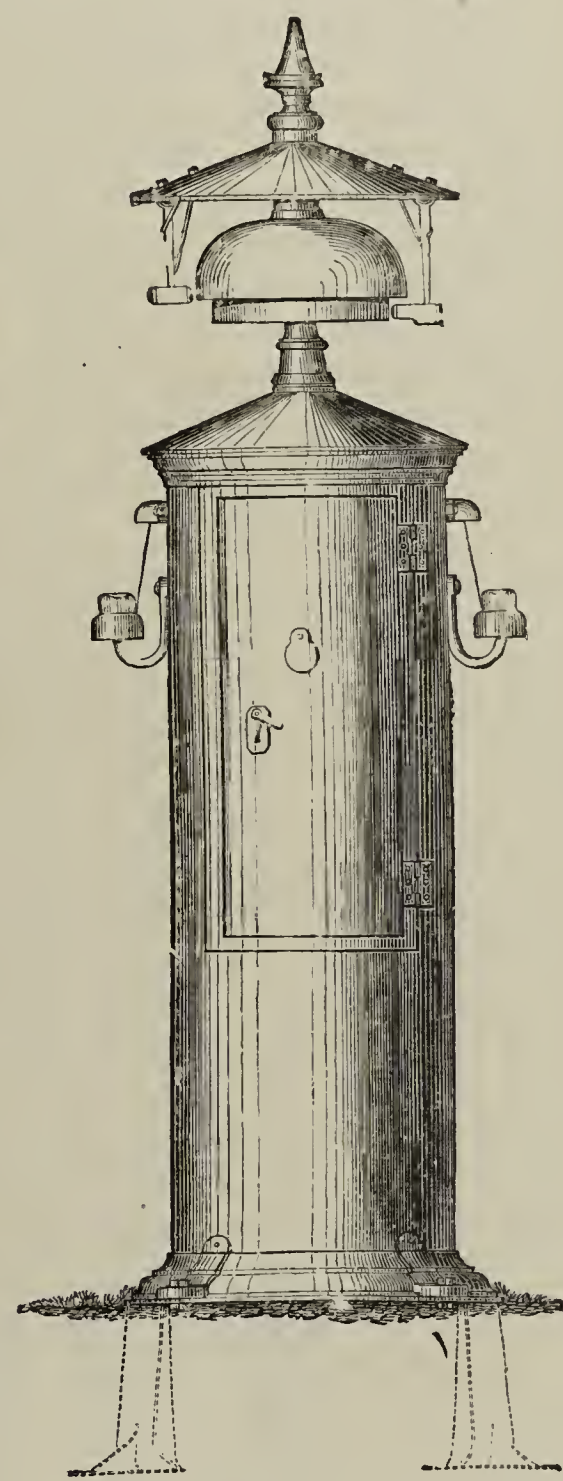

Fig. 4.

Where signal houses are not required, the gongs and spindle-alarums, with either single, double or triple bells, are placed on iron columns, as shown in Figs. 3 and 4.

Alarum lines with either the old form of apparatus and a battery, or with the new gongs and a magneto-inductor, form a complete signalling system, which is often employed independently of any other signalling or telegraphic arrangements. In many cases, however, the alarum line is combined with a line for telegraphic communication, and in other instances the alarum apparatus is provided with additional parts, by means of which gong

signals and telegraphic messages can be sent from any one alarum apparatus to the adjoining railway stations.

It is important that signal lines should be of simple and reliable construction. The object of railway signalling and railway telegraphy being principally to attain a well-regulated and safe control of the train traffic, telegraphic communication ought not to be permitted on signal lines, because intermediate stations would be excluded at times from an electric call or signal.

Notwithstanding the possibility of using one single line wire for telegraphic communications and alarum signals, it is undoubtedly much better to have two separate wires between the stations—one for telegraphic communication and the other exclusively for line signals (either bell alarums, block signals, or other signalling combinations).

We distinguish under the following heads, the two lines referred to above :—

I. Speaking telegraph (or correspondence) line.

II. Alarum or signal line.

I.—*Speaking Telegraph Line.*

For telegraphic communication between railway stations the improved recording instruments (normal inker) are recommended with relay, galvanoscope, key, lightning discharger and commutator, mounted on a specially constructed table which is fitted with spring contacts and the necessary wire connections.

II.—*Alarum or Signal Line.*

The alarum line is used for signalling the approach of a train to the men whose duty it is to look after gates at level-crossings, work semaphores, &c. The signals are sent from the station by means of the magneto-inductor and received by the gongs at level-crossings, &c., as above described.

The signals for help from any of the gongs to the stations are given by simply putting a key (such as shown in Fig. 5), corresponding to the number of the

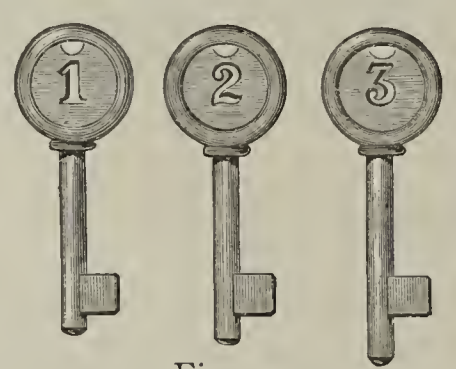

Fig. 5.

desired signal, into the keyhole of the spindle alarum and turning it once round ; the contact-wheel then rotates, and the signal is transmitted. The keys are numbered to correspond with the number of the message or signal to be sent.

In Messrs. Siemens' new gong-alarums the keys have been abandoned, and a number of contact wheels (Fig. 6), each representing a certain signal, are provided. These being placed on an axis, as required, and caused to rotate

No.	Contact Wheels.	Signals for help.	Signification of Signs.
1		— -	Engine broken down.
2		— — —	Train off the line.
3		— — — — -	Auxiliary engine wanted.
4		— — — - ▫	Stop all trains.
5		— — ▫	Men and doctor wanted.
6		— — — -	Train must be taken back.

Fig. 6.

when the clockwork is started, the current is interrupted and the signals transmitted.

When sending a signal for help the alarum apparatus has simply to be kept rotating until an "understand" signal is received from the adjoining stations. This answer is sent by means of the magneto-inductor, which sets in action all the gongs between the two stations from which assistance is wanted, thus warning the men of that section that some signals for help are being exchanged.

Fig. 6 shows examples of different contact-wheels, the signals which they give on the strip of the recording instrument at the receiving station, and the signification of such signals.

In order that the stations should know from which place signals are being sent, each gong is numbered, and contains a special contact-wheel, which is brought into rotation and sends its number to the nearest station. This number is always sent after the signal for help has been acknowledged.

By means of the special contact-wheels, numbers are signalled in the following manner :—

1 = .	6 = . —
2 = . .	7 = . . —
3 = . . .	8 = . . . —
4 = ...	9 = ... —
5 = —	10 = — —

The contact-wheels are kept out of circuit until they are required. This is effected by using a commutator. The commutator consists of a small square base, on which are terminal screws, carrying two brass connecting bars. Each

of the four terminal screws is connected to a leading wire. and the bars are placed either in the horizontal or vertical position.

The aggregate number of Siemens' gongs in use at the present time is over 24,000, distributed over England, France, Germany, Austria, Russia, Holland, Belgium, Denmark, Switzerland, Norway, Sweden, Brazil, Chili, &c.

CORRESPONDENCE.

ELTHAM, KENT, April 1882.

To the Editor of the "RAILWAY ENGINEER."

SIR,—At page 106 of your issue for the month of April the following paragraph, Numbered 2, appears in a circular issued by the owners of the Self-Acting Pressure Air Brake, wherein two things are attempted to be argued: First, that the failing to act of the Self-Acting Brake in question was not the cause of the Blackburn accident, as reported to the Board of Trade by its duly appointed officer. Secondly, that such a class of failure belongs to Non-Automatic Brakes.

I shall not discuss the first, but I enclose extracts, from the Board of Trade Continuous Brakes Returns, thoroughly disproving the second, and by inference making it more likely that the accident was caused by the brake failing to act properly when required, as per heading No. 1 in the Board of Trade Continuous Brakes Returns; published half-yearly.

Paragraph No. 2.—"Everyone must be struck by the introduction of so much irrelevant matter concerning automatic brakes generally, and about the so-called failures of the Westinghouse Brake by applying itself at improper times, whereas, he (Colonel Yolland) alleges the Blackburn accident to have been caused on the contrary by the failure of the brake to act when required, a class of failure which is well known to be peculiar to and inseparable from non-automatic brakes on account of their defective principle."

I prefer styling the brakes "Simple" and "Self-Acting," the latter term supplanting the word "Automatic." I do not admit the logical deduction sought to be introduced in the paragraph quoted, viz., that, because any self-acting brake may apply itself constantly when not required, that it results it will be sure to act when it is required; examples are not wanting whereby to prove the contrary, in fact I can point to more than one case of severance of trains (the only special occasions that the Board of Trade wish to cover by self-acting mechanism) where this very brake did not apply itself to *both* sections of the trains. If the self-acting system of a brake is to prove itself to be truly reliable, it is here, when a train becomes divided, that it must begin to advertise its perfection. Failing in this respect, it can be more capable still of failing to act on other occasions.

If the inventors and owners of the other self-acting brakes had relegated the faults under heading 1 to certain brakes, including the Westinghouse Self-Acting, but omitting several of the simple brakes, the arguments would have stood the test of enquiry, as the figures I furnish will show; in fact many millions of miles have been run by the latter without any faults under any of the three headings given in the Continuous Brakes Returns.

I have only now to deal with heading No 1, which embraces the class of failure under discussion, such as the Blackburn disaster, &c., &c.

The following are the Board of Trade instructions for returning accidents under that heading:—

"Failure or partial failure to act when required in case of an accident to a train or a collision between trains being imminent."

This heading was first introduced into the Continuous Brakes Returns in the half-year ending June 30th, 1880.

The two years, 1880, 1881, show that over 100 millions of miles have been compassed by self-acting and simple brakes.

In that period there are thirteen faults recorded under heading No. 1.

The various self-acting brakes, which are inserted in the Board of Trade Returns as appearing to comply with the recommendations laid down, excluding the Westinghouse, compassed in the two years 8,380,000 miles and no fault, under head 1.

The Westinghouse Self-Acting Brake, 20,000,000 miles, with 5 faults, under head 1.

Total miles run by Self-Acting Brakes, 28,380,000 miles.

Various other Brakes, in their simple form, 8,000,000 miles, with no fault, under head 1.

Clark and Webb Brake, 35,070,000 miles, with 4 faults, under head 1.

Simple Vacuum Brake, 28,870,000 miles, with 4 faults, under head 1.

Totals, 100,320,000 miles, 13 faults.

So that there are five against the Self-Acting Westinghouse Brake in twenty millions of miles. Whilst the Simple Vacuum Continuous Brake had one fault less on nearly 45 per cent. more mileage. The brakes of other inventors,

Simple and Self-Acting, compassed over sixteen millions of miles, free from record under head 1.

From this evidence it would appear to be more correct to say that these failures are "peculiar to and inseparable from" the Westinghouse Self-Acting Brake in a greater degree than the other systems, be they "Simple," or be they "Self-Acting."

I find that in three years and a half the Simple Vacuum Brake has run eighteen millions more miles than the Self-Acting Pressure Air Brake.

I am Sir, yours obediently,

FREDK. T. HAGGARD.

OFFICIAL REPORTS ON RECENT ACCIDENTS.

Major-General Hutchinson has reported the result of his inquiry into the circumstances connected with the collision which occurred on the 4th September last, near Penton station, on the Edinburgh and Carlisle section of the North British Railway. The immediate cause of this collision—in which an express passenger train which started from Carlisle at 3.37 a.m. overtook and came into violent collision at about 4.4 a.m., near Penton station, 16½ miles from Carlisle, with a special goods train which had started from Carlisle at 2.55 a.m.—was due to the carelessness of the driver (Gillespie) of the express train in not keeping a proper look-out for the down home-signal at Penton station. The down distant-signal for this station is visible a long distance off, and it is quite possible the driver may be correct in stating that when he first saw it it was showing a white light, as the night porter at Penton station may not have had time to put it to "danger" after the goods train had passed it. Gillespie's great error consisted in satisfying himself with this one sight of the distant-signal, for he acknowledges that for the 530 yards during which he might have seen the down home-signal, he never observed what it was showing, nor did he see till he was close to it the van of the goods train, though the tail lights must have been visible for about 175 yards. It is evident, therefore, that Gillespie was not keeping a proper look-out. Had he been doing so, and had he used the brake power (a continuous air-brake on the engine and tender and on two out of the six vehicles composing the train, one of the two having been a Pullman sleeping-car, twice as heavy as an ordinary carriage) he had available when he could have first seen the home-signal, he might in the 900 yards which intervened between this sight and the point of collision have stopped his train, considering the rising gradient of 1 in 100 which prevailed for 600 out of the 900 yards. As it was, his engine struck the van of the goods train, without his having previously seen anything of it, at a speed of some 40 miles an hour, and ran about 90 yards before it stopped. Evidence was adduced at the inquiry tending to show that Gillespie was under the influence of drink at the time of the collision and later on. The station-master at Penton saw him about a quarter of an hour after the collision, and judged from his manner of expressing himself, and from his smelling strongly of spirits, that such was the case. The station-master at Newcastleton, the adjoining station north of Penton, who saw Gillespie about 6, formed the same opinion from his speech and general demeanour, though he acknowledges that about an hour later he seemed to walk steadily. The station-master at Longtown, the adjoining station south of Penton, saw Gillespie soon after 7, and judged from his appearance that he was the worse for liquor, though he spoke sensibly and could stand steady. Gillespie himself acknowledges that, not feeling very well, he had one glass of whiskey in the first-class refreshment room at Carlisle just before leaving, and that after the collision, between 6 and 7 a.m., a passenger gave him another glass of whiskey at Penton. On the other hand, Colonel Lindsay, Royal Engineers, a passenger in the express train, hearing that Gillespie was suspected of having been the worse for liquor, made a sworn affidavit before a justice of the peace at Aberdeen that he had seen and spoken to Gillespie after the collision, and that, to the best of his belief, he was perfectly sober, and that he particularly remarked the calmness of his demeanour. The chief inspector of permanent way in the northern section saw Gillespie at about 7.15 a.m., spoke to him, and saw nothing to indicate that he was the worst for drink. Similar testimony is given by another permanent way inspector. A surface man had some conversation with him directly after the collision, and saw nothing to indicate that he was the worse for drink. Upon consideration of this evidence the conclusion may, I think, be arrived at, that though Gillespie failed to keep a proper look-out for the Penton home-signal, his negligence is not to be attributed to his having been the worse for liquor. The fireman states that he was firing on approaching Penton, and knows nothing of the state of the signals. The guard of the train also did not observe the Penton-signals, for which he had no excuse, and is deserving of blame accordingly. The next cause of this collision was the non-observance of the rules for the running of goods trains in front of passenger trains. The guard is the person held responsible for a goods train being shunted clear of the main line ten minutes before a passenger train is due, and in

accordance with this rule it had been arranged between the driver and guard that the special goods train should shunt for the express, if running to time, at Longtown, 9½ miles from Carlisle, which, as the goods train had a start of about 42 minutes, would not have been an improper arrangement. As, however, the train was leaving the goods yard a yardman came to the engine with a telegram in his hand, and informed the driver that the express train was, as the driver says he understood him, 26 minutes late (though the yardman declares he told him what the telegram stated viz.. that it was five minutes late). Upon this the driver remarked to the fireman that they would have plenty of time to reach Newcastleton (24¼ miles from Carlisle), and there shunt for the express; and accordingly without any communication with the guard, the driver started, was stopped nowhere by signal, and when running slowly just beyond Penton, having taken about 70 minutes to run 16½ miles, of which from 20 to 25 minutes had been consumed in running the last 2½ miles, he was overtaken by the express. This goods driver is, therefore, clearly to blame for having left Carlisle goods yard without previously consulting his guard as to the expediency of shunting at Newcastleton instead of at Longtown. There seems to have been unreasonable delay in the contents of the telegram announcing that the express was five minutes late at Skipton, which was despatched from the Citadel station at 2.15, not reaching the yardman till 2.40 a.m., and in his again not communicating its contents to the driver of the goods train till nearly 3 a.m. Another principal cause of this collision was the want of proper means for working the traffic on this important line of railway, where express and special trains are continually running. The use of the block system is the only really effectual method of preventing such collisions as the present; but failing this, it is certainly most necessary that telegraphic information should be furnished, not only by day, but also by night, to stations where there are shunting sidings—such as Longtown and Riddings junction—as to the running of trains, so that the signalmen there may know how to deal with slow trains likely to be overtaken by fast ones. Had such information been communicated to either Longtown or Riddings in the present case, the goods driver's mistake and breach of rules would not have led to the very serious collision which ensued, as he would have been stopped and ordered to shunt at one of these two places.

Major-General Hutchinson has also reported the result of his inquiry into the circumstances connected with the collision which occurred on the 13th September last, near Patrickswell station, on the Waterford and Limerick Railway. The immediate causes which produced this collision are, I think, to be attributed to faults in the servants of the two companies in charge of each of the trains. In the first place the driver of the Cork direct train stopped at Patrickswell needlessly far (at least 120 yards), from the tail of the Foynes train, which latter was detained there owing to a hot axle in one of its carriages. Had he contented himself with a distance of fifty yards he would not have run any risk, and the tail of his train would then have been well within the Patrickswell down distant-signal, whereas it was left 40 or 50 yards outside it. In the second place, the rear guard of the Cork direct train, though aware that his train was travelling with a ticket and that another train must be following, did not use as much despatch as he might have done in going back to protect his train as it was drawing slowly in to the Patrickswell distant-signal. He himself says that he had got back about 100 yards when he saw the engine of the Tralee train, and then observing that the driver was trying to stop, ran forward to try and get his train moved ahead; but the Tralee driver denies having seen him till just before the collision, when he (the guard) was close to his van. In the third place, the driver of the Tralee train, who had been properly warned before leaving Limerick that the Cork train was in front of him, could not have been approaching Patrickswell with sufficient caution, and did not use all the means in his power for stopping, otherwise if prepared, as he ought to have been, to stop if necessary at the distant-signal (which was admittedly at danger) by the application of the ordinary brakes, he should have been well able by the reversal of his engine and the application of steam the reverse way, considering too that he was running on a rising gradient of 1 in 113, to have stopped fifty yards outside it, having, as he himself acknowledges, caught sight of the van of the Cork train at least 400 yards off. As it was, however, though he reversed his engine soon after first catching sight of the van, he did not put on steam the reverse way till, as he says, within thirty or forty yards of the van. There are great discrepancies as to the time at which the collision occurred, the driver of the Cork train making it 6.50, the guard 6.52, the driver of the Tralee train 6.46, the guard 6.47, the Patrickswell station-master 6.41, directly after the starting of the Foynes train; and there are similar discrepancies as to the time at which the Cork train stopped outside Patrickswell station, the driver making it 6.47, the guard 6.50, the guard of the Foynes train 6.38, the Patrickswell station-master about 6.35. The gatekeeper at Nestor's crossing, about 1,000 yards from the Patrickswell distant-signal, makes the times of the three trains passing his post 6.25, 6.33, and 6.49 respectively, but he appears to have merely guessed at these times, and not to have consulted his clock, which was in his house close by. It is impossible to reconcile these discrepancies, but it is hardly likely that the Cork direct train, which left Limerick at 6.25, could have passed Nestor's crossing (6½ miles from Limerick) at 6.33, as stated by Nestor, or that the collision could have occurred at 6.41, as stated by the Patrickswell station-master. Judging from the whole of the evidence it

is more probable that the Cork direct train stopped outside Patrickswell station at about 6.45 p.m., and that the collision occurred at about 6.50. Though this collision was directly brought about by the above-mentioned causes, it would probably have been prevented (1), if the line had been worked on the absolute block system; (2), if the Tralee train had been provided with more brake power applicable by the driver; (3), if the down distant-signal had been placed at a greater distance from the down home-signals, viz., 700 or 800 yards instead of only 285 yards. This collision brings to light the objectionable practice of backing the Waterford and Limerick Company's Foynes and Tralee trains out of Limerick for a distance of about half a mile so that the engine may then be in front of its train.

Major Marindin has reported the result of his inquiry into the causes of an accident which occurred on the 15th October last, between Blaenau-Festiniog and Tany-Grisiau, on the Festiniog Railway. It appears from the evidence, and from the result of an examination of the site, that the line on both sides of the place where the accident occurred was perfectly correct to gauge, but that a few feet nearer to Blaenau than the point, 18 feet west of a diamond crossing, where there was the first mark of any wheel having left the rails, the right hand rail upon which this mark was found, and which is the outside rail of the curve, was, for a distance of about two feet nearly $\frac{1}{4}$ in. lower than the left rail. The permanent way was otherwise in excellent condition, and I attribute the run-off to the bending of one of the axles of the workman's carriage, caused probably by a sudden lurch when running over the low place in the rail. This axle, which was found after the accident to be bent and cracked just inside the boss of the wheel, was broken through in my presence. The fracture showed the metal to be of good quality, but there was the mark of an old hair crack extending from $\frac{1}{8}$ in. to $\frac{1}{4}$ in. into the metal, over about $3\frac{3}{4}$ in. of the total circumference of about $6\frac{3}{8}$ in. I do not think that it is possible that this hair crack can have commenced since the carriage left the shops, and under these circumstances it ought to have been detected if any examination of the axle had been made when the new wheels were fitted to it. These workman's carriages are nothing better than slate wagons with covers to them, and I am not aware that any Parliamentary or other sanction has been given for the conveyance of passengers, even at reduced fares, in such vehicles, which are undoubtedly less safe than the third-class passenger carriages in use upon this line. It appears that the upsetting of the carriages did not occur until the train was being pulled up, and, as these narrow gauge vehicles are undoubtedly more than usually liable to turn over if they leave the rails, it would be well to caution the drivers on this line to pull up very gradually whenever they perceive any such accident to have occurred unless there are some other reasons for stopping as quickly as possible. It should be remarked that this is the first accident to any passenger train which has taken place upon this line since it was opened more than sixteen years ago.

Major Marindin has also reported the result of his inquiry into the causes of a collision which occurred on the 27th September last, at Merton Abbey station, on the Joint London and South-Western and London, Brighton, and South Coast Line, between Streatham junction and Wimbledon. From the evidence it appears that the down goods train, which, owing to delays upon the road, was nearly $1\frac{1}{2}$ hours late, arrived at Merton Abbey station at 10.17 p.m.; that the whole of the train, except the engine and one wagon, was left standing on the down line, with the rear brake-van about 15 yards inside the down home-signal; and that it was in this position when the collision took place, at which time the passenger train was running at about 12 miles an hour. The engine of the goods train was engaged in shunting operations on the sidings and the up line, and it was not until about 10.40, according to the station-master's evidence, or 10.46, according to the evidence of the guard of the goods train, that the former gave orders for the goods train to be shunted on to the up line out of the way of the passenger train due at 10.47. There was some delay, owing to some wagons having been pushed foul of the cross-over road points, and these points had only just been pulled over for the engine to cross back to its train when the collision occurred. It is certain that permission had not been given on the block instruments for the passenger train to leave Tooting, and the questions to be decided are whether the driver of the passenger train received the proper signal to start from Tooting, and whether the distant-signal from Merton Abbey was or was not at danger. The driver states that when his guard gave him the usual signal that the train was ready to leave Tooting it was so foggy that he could not see the starting-signal, but that on drawing up to it he found it off, and started away; but the evidence not only of the signalman and porter at Tooting, but to some extent that of his own guard, proves conclusively that he run past this starting-signal at danger. He further states that the Merton Abbey distant-signal was off for him, but here again his guard's evidence is against him. It is certain that by the interlocking in Merton Abbey signal-box the lever of this signal could not have been pulled over; and the evidence of the driver and guard of the London, Brighton, and South Coast goods train proves that this signal was showing a proper red light when they passed it; but, more than this, the driver of the passenger train is condemned out of his own mouth, for he states that the signal was showing a "white light with a little bit of red," and afterwards admits that he knew that this signal ought to show a green light when it is all

right; so that even by his own admission he ought to have treated the signal as a danger signal, as it was not showing the proper light. As a matter of fact the signal does not show a white light under any circumstances, and it is clear that not the smallest dependence can be placed upon the word of this driver. The evidence as to the fog is a little contradictory; but it was no doubt a thick night, the fog being partial, and probably preventing the signals from being seen for over 200 yards, or even less at places. This collision was, beyond question, due to the gross carelessness of the driver of the London and South-Western passenger train in running past two signals at danger; but the risk of such an accident ought never to have been run. There was no possible reason why the goods train should not have been placed upon the up line to do its shunting as soon as it arrived at Merton Abbey, and the conduct of the station-master in leaving it upon the down line until the passenger train was nearly due is deserving of censure. He states that it was at 10.40 that he first gave the order for the engine to go across to shunt the train clear of the down line, but the evidence of the guard and driver of the train is to the effect that this order was not given until some minutes later, and I suspect that no order was given until after the Tooting signalman sent the message on his speaking instrument to hasten the clearing of the line. It is true that the accommodation at Merton Abbey is very small, and that shunting is carried on under difficulties; but that should have made the station-master all the more careful to take steps to have the down line cleared in ample time before the passenger train was due. The driver of the passenger train might, perhaps, have lessened the speed of his train before the collision if he had had a continuous brake at his command; but no continuous brake will prevent collisions when drivers run wilfully past signals at danger. It should be observed that the injuries to the driver and fireman of the passenger train would probably have been far less severe if the engine had not been running with the proper trailing end in front; and it is this additional risk to the men upon the engine which is one of the principal reasons for objecting to the running of either tank or tender engines in this position.

Major Marindin has also reported the result of his inquiry into the causes of an accident which occurred on the early morning of the 23rd September last, between Romsey and Dunbridge stations, on the London and South-Western Railway. This collision was due principally to the carelessness of the signalman at Dunbridge station in giving "line clear" to Romsey after the first half of the 11.40 mixed train had passed his signal-cabin, although he admits that he did not see any tail-lights on this portion of the train. He states that he thought that it was the light-engine which had passed, and which had got in front of the 11.40 train, but he had no right to assume this, or, according to the rules, to give "line clear," unless he actually saw the tail-light, whether it was the train or the engine. This mistake of the signalman ought not, however, to have led to an accident, provided the brakesman of the mixed train had been prompt in taking the proper steps to protect his train when he found that it had come to a stand. He evidently did not at first realize that his train had parted; but whether it had done so or not it was equally incumbent upon him to go back at once to protect the train, and instead of doing so he clearly wasted time in talking to the passengers. The statements as to the side-lights and tail-lamps of this train are very contradictory, but the weight of evidence is in favour of the assumption that they were burning, if not brightly, certainly sufficiently well to have been seen for some distance, and I believe, therefore, that the driver and the fireman of the light-engine were not keeping a proper look-out. The signalman at Dean seems to have been equally careless with the signalman at Dunbridge, while the driver of the mixed train ought, in my opinion, to have found out sooner that his train had divided, and, being on a rising gradient, to have stopped his train at the first signal-box he arrived at after doing so. Altogether the conduct of most of the servants of the Company concerned is not very creditable to them. I am unable to assign any reason for the parting of the coupling, which gave way at the pin of the shackle, as the iron was of good quality; but this accident is only another instance of the additional risk attendant on the running of mixed trains, in which trains the wagons should at any rate be securely coupled, with side chains as well as centre couplings.

Colonel Rich has reported the result of his inquiry into the circumstances which attended the collision that occurred on the 9th of September last at Ambergate station, on the Midland Railway. It appears from the evidence that on the day in question the engine-driver of the mineral train, after its arrival at Ambergate from Swanwick, about 12 o'clock was engaged in shunting his train in the sidings at the east side of the North junction. When he had completed the shunting, and was ready to start on the return journey, he whistled for the signal, as he intended to run round the triangle, so as to get his engine in front of his train for his return journey to Swanwick. About seven minutes after he whistled the signalman made the siding-points and lowered the siding-signal for the train to run out on to the main line. The signal-man had previously obtained "Line clear" from the West junction, through which junction he intended to send the mineral train, but he forgot to alter the points at the north end of the triangle, through which the passenger train had run up to Ambergate station, and the mineral train ran along the same line of rails as the passenger train. The engine-driver of the mineral train did not observe that the

passenger train was standing at the station until his engine was within twenty or thirty yards of it; and although he reversed, and his fireman applied the tender brake, he could not stop his train before the engine struck the van at the tail of the passenger train at a speed of about four miles an hour. A porter, who was standing on the opposite platform, observed the mineral train and ran towards it, shouting and holding up his arms, so as to attract the driver's attention and stop the train; but this was not observed by the men on the engine of the mineral train until it was within a short distance of the passenger train. The collision was caused by the mistake of the signalman in the north cabin, who has been employed for about ten years as signalman in the Midland Railway Company's service, and has never made a mistake before. He cannot account for his mistake in the present case, except that his attention was taken up by a special goods train which was working in the sidings on the west side of the line near his cabin, and by a telegraph message from Derby which he had to receive. The engine-driver of the mineral train could have seen the passenger train for about 120 yards before his engine reached it, in ample time to prevent the collision, if he had been on the look-out; but this man was running in full confidence that he was on a clear road, and he stated, that he observed that the signal for the line upon which he was running was at "All right." This possibly made him less alive to the obstruction. The signal which he observed at "All right" had been lowered for the passenger train to proceed from Ambergate station to Derby. The mineral train was intended to pass over three unlocked pairs of facing-points on the main line, in order to reach the West junction and get round the triangle. This operation entailed the occupation and blocking of six sections of railway, viz., one at each side of each junction at the angles of the triangle. It is desirable that this mode of working, which entails the fouling of the passenger lines, should, as far as possible, be avoided, and that additional signals should be provided, to show the drivers on which lines they are intended to run after leaving the sidings, and to lock the facing-points on the main lines over which their trains have to pass.

Major Marindin has also reported the result of his inquiry into the causes of a collision which occurred on the 15th September last, at the King's Cross goods yard, on the Great Northern Railway. This collision, in which one poor man was killed and two others very severely injured, was caused by an unfortunate mistake of the signalman in the goods junction signal-box. This man, having at 7.29 a.m. lowered the signals, and given permission for the coal train to leave Caledonian junction signal-box at the north end of the tunnel, within two minutes afterwards allowed two engines, which were coming out from the engine shed to shunt back on to the stone road, to come forward and foul the line upon which the coal train was running. He does not attempt to excuse himself, and states that he entirely forgot all about the coal train until the engines were past his box, and standing across the up goods line. He then remembered what he had done, and called out to the engine-drivers to set back, but too late, as one of them only was able to do so before the coal train came out of the tunnel. This train was probably running at a considerably higher rate of speed than fourteen miles an hour, the estimate of the driver; but there is no reason why it should not have been doing so, the signal being off for it, and no blame can be attached to any of the men on either of the two engines, all of them seeming to have done what they could to avert the collision. It is stated that the signalman was a most intelligent, clear-headed man, specially selected for this somewhat difficult post, and such a mistake on his part is almost unaccountable, for he had only been a short time on duty; there was no special pressure of work at the time, and the interval of time between the lowering of the signal for the coal train and the calling forward of the engines was only two minutes. The lines at this junction are so cramped by the piers of a viaduct carrying the North London Railway over them, and by those of another goods line viaduct, that it is impossible to alter them so as to make them quite satisfactory; but in order to provide for the safety of the junction, a down stop signal should certainly be fixed close to the fouling-point, which should be interlocked with the up junction signals, and which should on no account whatever be allowed to be passed when at "danger." The Company are prepared to do this; and in order to avoid delays in shunting operations, some alterations are to be made in the connections inside the junction, which will enable engines to come forward from the locomotive shed and coal lines to shunt back into the stone road without fouling the junction, which they must do in the existing state of the lines. Engines coming from the goods lines for this purpose will have to foul the junction, but they will have to stop at the new signal until it can be lowered for them.

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LEGISLATIVE ENGINEERING.

FROM early childhood we have been taught to regard the British constitution with reverent awe. The legislative machinery which has contributed so much to the prosperity and greatness of this country has been a favourite theme for historical encomiasts, both at home and abroad. We have yet to learn, however, that the Houses of Parliament are capable of solving the most difficult problem of mechanical engineering, or that a comparatively small Government department can decide off-hand a complicated question which is still a subject of doubt and perplexity to all the most experienced engineers of the day. When the Board of Trade, some few years ago, took upon themselves the responsibility of telling us the conditions necessary to the efficiency of continuous brakes, they did so under the advice of very able men who, although not practical railway engineers, were, nevertheless, in a position to command respect for their opinions. At that period there was only one brake prominently before the public which appeared to fulfil those conditions: and if railway engineers *en masse* had, with docile faith in the wisdom of the State, adopted that particular brake, a few people pecuniarily interested in the invention would have reaped a great fortune; but the railway companies would have discovered ere now that they had expended vast sums of money on apparatus dangerously unreliable, and already surpassed by inventions of far more simple and efficient character. It was manifest to men engaged in the practical working of our railways that with regard to continuous brakes we were in an experimental stage, and no independent professional adviser would recommend his company to adopt a costly and complicated brake which had not been tried long enough to justify a sound opinion of its merits, and which might at any time be put completely out of the running by superior inventions. A well-known Government inspector of railways threw his weight into the scale without affecting the general attitude of the most experienced railway mechanicians. Men who looked ahead could see the possibility of great changes; and Sir Henry Tyler's retirement from the Board of Trade, and public acceptance of the tempting offer made by Mr. Westinghouse, failed in its effect. Our locomotive superintendents, to whose verdict the companies look for a settlement of the brake question, were for the most part quite proof against the allurements of the rich American inventor. To their steadfast adherence to sound principles and their patient inquiry we are probably indebted for immunity from many terrible repetitions of the Blackburn accident.

It has been supposed that the public are not satisfied with the rate of progress made by our railway companies in fitting their trains with continuous brakes, and some Parliamentary agitation has been maintained with a view to keep up the idea. With an invention which has failed to make headway with the help of Board of Trade "Conditions," the absorption of an eminent railway inspector, banquets *ad libitum*, and repeated advances to every grade of railway official, we can understand a last dying effort to secure the aid of the State. Thus it is we see the Legislature asked to interfere in a question of pure mechanics, and to assume a responsibility entirely unprecedented.

Lord Colville of Culross has recently expressed in the House of Lords the general opinion of the railway world on the subject of Earl de la Warr's Railway *Coercion* Bill. Earl Cairns also stated the case very clearly when he said:—"By the Bill Parliament was asked to stereotype now and for ever, or, at any rate, until the Act was repealed, a sort of ideal brake, and to submit the question whether the brakes of the various companies answered the requirements of the Act to a body of gentlemen—the Railway Commissioners — who were utterly unfit to determine such matters.

In this absurd attempt to thrust upon Parliament responsibilities which are now borne by professional engineers of great ability and experience, it is easy to distinguish the hidden hand of the wire puller. The recorded failures of apparatus designed and patched up with great ingenuity to meet the Board of Trade requirements, prove conclusively that we must look to more simple forms of continuous brakes. In this direction the majority of practical men are now working, and the time may not be far distant when we shall arrive at such uniformity of opinion on the subject as will justify more energetic action on the part of the railway companies.

THE PROJECTION AND CONSTRUCTION OF RAILWAYS—COMMERCIALLY AND PRACTICALLY CONSIDERED.

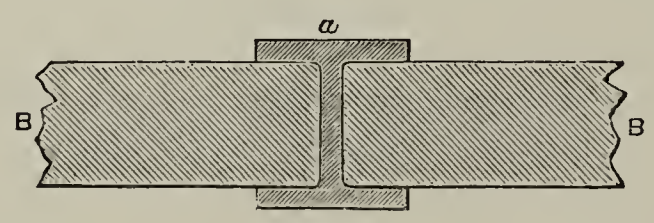
(*Continued from page* 119.)

THE question of stanchions requires serious consideration, for we have not only to consider the load upon such elements, but also the liability to fracture the wall if the stanchion is pressed against it in a direction at right angles to the course of the wall.

We must, therefore, rely upon the stability of the stanchion, *per se*, and it should be, under such circumstances, *clear* of the brickwork or masonry by which it is surrounded.

In some cases the stanchions *may* serve also the purpose of sustaining a weak wall ; such an arrangement is shown in Fig. 35—in horizontal section. It will be observed that

FIG. 35



the brickwork is built into the flanges of the stanchion, *a a*, and such stanchions have proved serviceable in sustaining 9 inch brick walls, which it has been found necessary to raise from a height of 6 feet to 12, and in this connection we may point out the special difficulty, which occurred in one case—the wall was built so that it touched the boundary of the land, hence no piers could be built behind it.

In the ordinary course we should now consider the signal arrangement, but as the history of signals is so fully exemplified in this journal there is no scope for further dilating upon it ; therefore, we proceed to the inspection of railways by the Government inspectors prior to their being opened for passenger traffic.

VII.—Inspection of Railways by Board of Trade Officials.

On giving the first notice to the Board of Trade of the desire to open a line of railway for *passenger* traffic, the engineer receives in reply a statement of instructions and printed forms in duplicate, to be filled up as described below ; only one copy, however, is required to be sent to the Board of Trade :—

The *locus* of a "fixed point," preferably the commencement of the railway or branch referred to, must be defined, and the distances of bridges, viaducts, and tunnels from that point marked upon the tabulated forms ; in addition to this, the spans, heights, and materials used in each structure must be clearly described, and it must be shown in the case of each bridge whether it is *over* or *under* the railway.

Tracings of all bridges must be supplied to the Board of Trade in addition to the verbal descriptions on the tabulated forms. Thus the officials have the means of checking the engineers' calculations, a somewhat important matter where iron girders are largely used.

We have known some engineers almost tremble at the name of Colonel Yolland, who we may fairly describe as one of, if not *the* most experienced man in the testing of iron structures. As an instance, many of our readers will remember the elaborate testing of the Saltash Viaduct, designed by the late Mr. Brunel, one which stands unrivalled for strength and excellence of construction. We can hardly speak of Brunel without regretting his loss, being, as he was, a *scientific* engineer, whose love of his profession outweighed all commercial considerations.

The first document is the book of Parliamentary Plans and Sections, with such deviations as have been made during the construction of the line *marked in red*. Upon this plan must also be shown the position and length of station platforms, and the heights of the latter are to be shown on the sections.

Second. A table of gradients and level portions, with positions of stations distinctly shown.

Third. A tabulated form showing in plan curves and straight portions of the line.

Fourth. A table of cuttings and embankments throughout the line.

Fifth. A table of bridges for roads crossed by the railway.

Sixth. A table of bridges and viaducts over water-courses and valleys.

Seventh. A table of all *level crossings* whether for public, private accommodation, or bridle roads or foot-paths.

Eighth. A table of tunnels ; on the margin of which should be shown the sections of the various tunnels, and also the sections of open arching which practically come under the same category, as when finished they may be regarded as tunnels, although they have been built in open excavations, which renders it necessary to put backing on the haunches.

Ninth. A table of aqueducts and culverts three feet or more in diameter.

Tenth. Permanent way to be described and illustrated, also the mode of fencing and drainage and the clear width of line. In all cases the fullest information should be

supplied to the Board of Trade, in order that its officials shall have no difficulty in satisfying themselves as to the stability and proper construction of the works they are called upon to inspect, and if the engineer has conscientiously designed the works, he need have no fear as to the results of the inspection.

We now come to the actual inspection of the railway by the official appointed by the Board of Trade.

In regard to the testing of iron bridges under (or carrying) the railway, this will be done by loading each bridge with a train of the heaviest locomotives in use on the system to which the line belongs. These engines will be run over the bridge, and will also be permitted to stand upon it, the deflections being taken under all conditions. The ordinary Board of Trade allowance for wrought-iron girders is one inch per 100 feet of span; but, of course, allowances varying from this are made in special cases, for the deflection of a girder considered without regard to the ratio of its depth to its span can be no test of its absolute strength, although, to some extent, it is a criterion of the amplitude of its vibration under a passing load, for it is evident that the greater the deflection the greater will be the rebound.

There is a point in connection with the question of deflection which, although obvious to men of extensive practical experience, may have escaped the notice of those who are only acquainted with ironwork as it *appears on paper*, and it is that the deflection test is a test of *workmanship*—if properly used. A wrought-iron girder is a built structure, and cannot be regarded as one entire piece. The material of which it is made may be tested in detail, and, assuming the workmanship to be perfect, the deflection under a given load *theoretically* calculated, but an experience extending over a quarter of a century has shown us that such calculations are scarcely ever borne out in practice, the actual result is either more or less than the calculated.

Where no great inconvenience is incurred, we should in all cases advise the engineer of the line to test his bridges prior to the Government inspection, and more especially in localities where carping wise-acres are running about among such as they can find more ignorant than themselves, spreading a notion that such and such a work is not strong enough to carry the railway.

It may seem that the deflection of a *built* girder being less than that calculated for a *solid* girder of the same material, is somewhat paradoxical, but we can explain that it is not so.

First we will take the case of an ordinary single web girder (of uniform section throughout) in which the entire section has been taken, and the modulus of elasticity of the iron being known, the deflection has been calculated as if the girder were rolled solid, and yet the deflection proved less than that expected.

This can only be accounted for by the manner in which the work is executed, a difference of rivetting in top and bottom flanges will cause initial tension on one or the other. If this initial tension be on the top flange it is evident that the actual rigidity of the girder will be in excess of the calculated rigidity, as that initial tension must be overcome by the load before the top flange is brought into compression; if, on the other hand, the initial tension is on the bottom flange, the load merely increases it. It would occupy too much space, and also be inappropriate here to show how, in the *manufacture* of a plate girder, an initial strain may be set up in *one flange*, and die out in the web, without affecting the other flange; but such is the case, and fully explains the apparent paradox in reference to our first case.

Now we will take the second case; that where the girders are formed with their flange plates arranged to suit as nearly as possible the varying strains, so as to approximate an uniform strain per sectional inch throughout, in such cases Stoney's rule is commonly adopted and the modulus of elasticity taken from an experiment on some such bridge. Here we have two sources of error; first, *there is not an uniform strain*, as the plates are not tapered to the curve of strain, but cut off with square ends, thus giving an excess of sectional area in some parts; second, the rigidity of the web is not taken into consideration in the calculation at all.

Certain (or rather uncertain) data have been given as to the moduli of elasticity of rivetted work, as follows:—Single web plate girder, 6,391 tons per sectional square inch; double web plate girder, 10,541 tons per sectional square inch; Conway Bridge, 8,372 tons per sectional square inch.

Now these figures were arrived at from the deflections exhibited under loads causing *transverse strain*, and that alone is sufficient to indicate to the *practical* man that they are no guide whatever for girders, other than those of *exactly* the same dimensions and construction as those from which the data were determined.

The writer of these articles has, out of curiosity, calculated the modulus of elasticity, from deflection of railway bridges *as erected*, in order to ascertain whether any uniformity existed, but although in single web girders of ordinary proportions he found it to average 6,901 tons, yet the variations were so great as to render the average factor useless, and to use the highest factor would mean to provide unnecessary weight in the girders, and here it must be remembered that although a strong bridge brings credit to the engineer, that credit must not be gained by wasting the money of the proprietors.

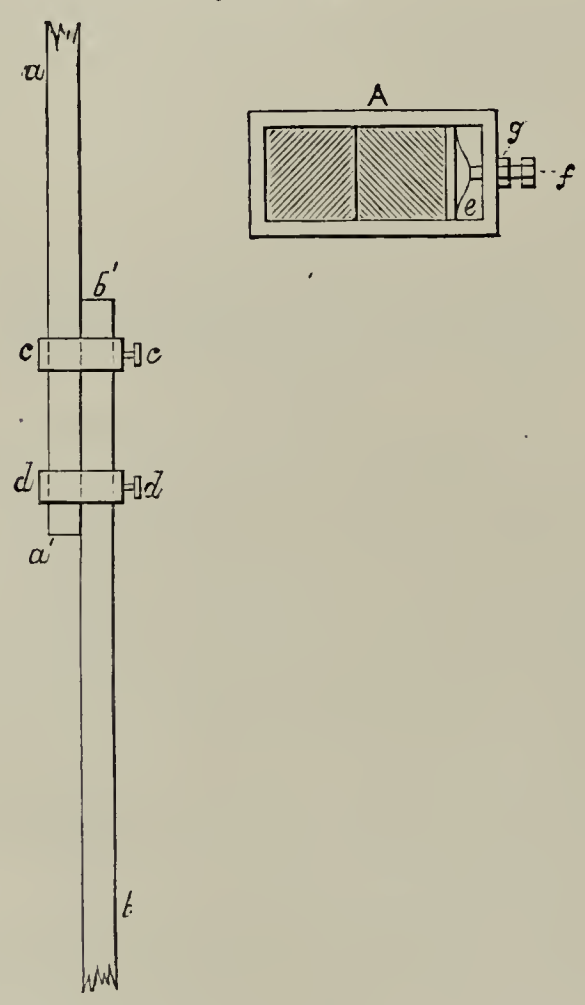
The deflection, which becomes permanent set, causedas some would say by the rivets "taking their bearing," should not occur in any work, as the rivets should thoroughly fill the rivet holes when the process of rivetting is complete, they should not *cool away* from the surrounding iron.

Most of this loose rivetting is worked down to a bearing by the contractors ballast trains before the Government inspection comes on, but there is a loss of strength, especially in joints wherein loose rivets occur, which should be jealously guarded against by the engineer.

The modes of testing will of course vary with the construction of the bridges. Some persons will rely upon the use of a levelling staff and level, this may be well enough for observing the deflection produced by a stationary load, but is hardly reliable to determine that produced by a rapidly moving load; therefore wherever they can be used, sliding rods are employed, these rods being constructed as follows:—

Two rods of such length that together they shall exceed by two feet or more the height from the ground to the underside of the girder to be tested, are clamped together as shown in Fig 36. $a^1 a$ is the upper rod, b^1 b the lower

FIG. 36.



rod; when these are adjusted, the upper end of a^1 a touches the bottom of the girder, and the lower end of the rod b^1 b rests upon the ground, or if that be not sufficiently solid a stone is bedded in it firmly to afford the necessary resistance. Of course, the ends of the rods should be shod with suitable ferrules. The rods are held in contact with each other by clamps, c c, d d, and the tightness with which they are pressed together must be such, that while it is sufficient to prevent their accidentally slipping, will allow them to slide upon each other under external force, *without their being bent under the strain.*

A convenient kind of clamp is shown in plan at A, the two rods being shown in horizontal section. In this arrangement the pressure is applied through a plate upon which a spring, e, acts, the amount of force being regulated by the set screw, f, which is furnished with a lock nut, g, to prevent its working loose when properly adjusted.

When the rods are in place and the bridge unloaded, a very fine pencil line is drawn on b b^1, corresponding to the bottom, a^1, of the upper rod; as the load runs over, the upper rod is depressed, and so remains, another pencil line is drawn on b b^1, corresponding to the altered position of a^1, then the rods being sufficiently drawn apart, the distance between the two pencil lines will be the amount of deflection, which can of course be measured off by a suitable scale.

Three of these pairs of clamped rods should be used for testing a girder, in order to arrive at the *actual deflection* of the structure.

One pair is to be placed under the centre of the girder, and one under each end, as near to the abutment as possible. This will obviate certain errors which would otherwise occur.

There will always be some subsidence of the bed plates under the load on the bridge, part being due to the compression of material upon which the girder is bedded and part to the temporary yielding of the ground upon which the foundations of the abutments rest; thus, by taking the mean of the end subsidences, as measured by the rods, and deducting it from the central deflection, also registered by the rods, the *actual deflection of the girder* is found. By following this course, we also avoid any *quibble* about the compression of the rods themselves, as they will all be made with the same over-lap and adjustment and of the same lengths, so that the friction being the same on each pair the elastic compression will be the same for each of the three pairs. This compression is practically inappreciable, but we mention it as it is possible some super-academical junior might be inclined to bring it forward in order to air his fledgeling acumen.

The simplest form of bridge to test is one so constructed that there is a longitudinal girder under each rail, then each girder having been tested as above described, the work is at an end. In this case, the deflection will be less than what might be expected from the results of tests made on *each girder* prior to the erection of the bridge, for, although it is not included as an element of strength in calculating the structure, yet the floor gives a very great amount of additional rigidity—it virtually acts as an extension of the upper flanges of the girders.

Taking next that form of iron bridge which consists of two main girders, carrying on their bottom flanges cross-girders upon which the rails are supported, we find that the deflection of the cross-girders must be determined as well as that of the main girders; this deflection will usually be very small, as the cross-girders being *rigidly fixed* to the main girders they stand *partially* under the conditions of girders fixed at both ends, although they are always (by

practical men), calculated as girders freely supported at each end. We use the word partially because the rigidity of their fixture is limited by the lateral stability of the side or main girders.

The iron bridges over the railway do not get tested as a rule by the Government Inspector, in fact, there are very great obstacles in the way of such a course, and the officials being satisfied by the tracings forwarded to them of these structures (unless the bridge over the railway carries *another* railway), they pass untested, but leave a responsibility upon the proprietors of the line, for they must be sufficiently strong to carry a twenty ton traction engine amongst the rest of the load.

As a matter of course, the engineer will accompany the Government Inspector over the line, in order to explain any matter that may arise as to foundations, &c., and it is advisable that he should furnish himself with tables showing the calculated strength of the various iron structures on the line.

We advise this table to be prepared with columns furnishing the following information :—Name of bridge or of road or river crossed by it ; distance of bridge from the "fixed point" ; total weight of iron in bridge ; dead load per line of railway ; total running load (in addition to dead load) required to fracture the girders, per line of railway ; the same reduced to per foot lineal per line of railway ; two similar columns showing in like manner the running loads corresponding to the strain of five tons per sectional square inch (allowed by the Board of Trade) ; a column showing the tensile and compressive strains per sectional square inch under the maximum load that can be brought upon the girders by a train of the heaviest locomotives to be used on the line ; a final column to be left blank for remarks, and for noting the actual deflections of the girders during the inspection. The cross girders (where there are any) will not admit of similar treatment, for these must be given the running load per girder necessary to cause fracture, and also the maximum running load per girder, and the corresponding tensile and compressive strains per sectional square inch. In calculating the breaking loads, the factor should be taken from the ultimate tensile resistance of the iron used.

In regard to the table for bridges carrying roads, all that can be shown is the tensile and compressive strain per sectional square inch under the maximum load to which it can be subjected, this will be for a crowd 120 lbs. per superficial foot, but the extra weight due to a twenty ton traction engine, *placed in the centre*, must be considered. The calculation must therefore be made as follows :— First calculate the strains for an uniform load comprising the dead load of girders, ballast, &c., and 120 lbs. per superficial foot of roadway for a crowd ; next calculate the strains due to the twenty ton traction engine, having deducted from its weight, the load of 120 lbs. per square foot taken *over the area occupied by the traction engine*, the sum of the two sets of strains will give the required result. In masonry and brickwork structures, the great question to be considered is the stability of foundations and proper proportioning of the arches, the latter the officials can satisfy themselves about from the tracings sent them, and also in regard to large and heavy bridges and viaducts it is advisable to be provided with sections of the ground as ascertained by bore holes, or from a record of the strata passed through during the excavation of the soil, for the foundations of piers and abutments.

In the special train provided to convey the inspector over the line, it will be found that in passing through tunnels he will place the carriage door on the side nearest the tunnel wall wide open, in order to satisfy himself that it clears throughout, the same remark of course applies to open arching.

In all standing works higher than 2 ft. 6 in. above rail level, there must be a clearance of 2 ft. 4 in. between such work and the outside of the widest carriage or engine used on the line.

While speaking of clearance we may mention that no standing work (such, for instance, as a column supporting a roof) must on a platform be nearer to the edge than 6 ft., and as we have known ourselves of one case in which they had to be altered for matter of an inch or so, it is advisable to allow in the designs a more ample clearance, say 6 ft. 3 in.

We next come to the inspection of the signal arrangements. It is a matter of no importance to the Government Inspector whose system is adopted, so long as it answers the requirements of the Board of Trade, but strict as the rest of the inspection may be, this part is that which seems to be most perseveringly conducted, probably because in a great number of cases the engineers to the lines know, practically, nothing about the interlocking gear, and therefore have to depend upon the manufacturers for the arrangements adopted on their lines.

The signalling arrangements for new branches from an existing trunk line, whether that branch be constructed under the direction of the engineer of the main line, or under that of an independent engineer, will usually be made by the superintendent of the signalling department of the main line, and it is necessary that this course should be pursued in order that an uniform method may obtain throughout the system.

There are two points of view from which the signalling will be examined ; first, as to the conspicuousness of the signals themselves, and, second, as to their correct interlocking with the points and the reliability of the locking gear generally. The signal posts must be of such height and so placed that the engine driver can see the signal at a sufficient distance, and arranged so that he does not subsequently lose sight of it until he has passed it. This

will in some cases necessitate the use of two signal arms for one signal; for instance, in passing under a long bridge at some little distance from the post, the driver will not be able to see the *high* signal arm, therefore there must also be provided a *low* signal arm, visible under the bridge.

With a perfect locking gear it is impossible to exhibit a wrong signal, and although the signal may be a thousand yards from the signal cabin an electrical repeater will indicate to the signalman whether or not the signal arm is in its proper position.

It may here be noticed that the normal position for a signal is "danger," and from that position it is to be drawn to permit a train to pass, after which it must return to the normal position. Signals must be so weighted that if the signal wire breaks they will fly to danger.

VIII.—Conclusion.

In concluding these articles it seems advisable to offer some general considerations, more of a commercial than technical character, which may be of some service to the younger members of the profession.

When a young engineer embarks in practice for himself as a railway engineer, it is well that he should first sit down and "count the cost," then if, looking matters squarely in the face he is content to pursue the venture, there is nothing more to be said about it, but it is always a very speculative matter, and years of life may be literally thrown away without any, even remote, advantage arising; on the contrary, every year inactively and unprofitably spent reduces the capability of the man to deal with business, such experience as he has previously gained fades, and he gradually becomes enervated, and ultimately lacks the energy necessary to enable him to seize upon such opportunities as do arise.

Consider the case of a pupil fresh from his articles, setting up on his own account as a railway engineer, what possible chance can he have? Common sense would protest against such a course, which only consummate self-esteem can indicate. It will no doubt occasionally happen that some weak-minded youth is so puffed up by the admiration of his talents exhibited by his *non-professional* friends, that he fancies he has but to mount his name on an office door to find a fortune at his feet, in this case he is more to be pitied than blamed.

There is a criterion which should by no means be neglected by a pupil who, towards the expiration of his articles, contemplates attempting to practice; let him ask his master to retain him as a salaried employé; if he really possesses the energy, business habits and love of his profession, and has acquired also the necessary practical knowledge of each branch of his profession, to enable him to fight the uphill battle against age, matured experience and influence, that master, having perceived his worth, will be unwilling to part with so valuable an assistant, and accordingly engage him; but if the application is not acceded to, it may be taken that he does not possess the exalted qualities necessary to ensure success.

The only kind of opportunity which offers a prospect of success, is the chance of being admitted to a partnership with an engineer already in practice and established in position.

A *good* partnership is a very difficult matter to get at, for it is certain that if a man has a *really lucrative* practice, he will not care to share it, for even if it overweights him with work, he can always relieve himself by employing competent assistants *for whose time he will be paid* by the companies employing him.

On the other hand, if a partnership is obtained with a man who accepts it on account of the capital forthcoming, that in itself is an indication that his affairs are not in a very flourishing condition.

We will now assume an example where a young engineer has started to try and work up a railway practice, and suppose that he has been engaged to prepare a scheme for Parliament.

So long as he has been brought up in a railway engineer's office, he will know the routine of Parliamentary work, and therefore should have no difficulty in preparing the Parliamentary plans, and even if he is deficient in the necessary knowledge, he can hire assistants competent to do the work. The pinch, however, is when the Bill comes on before Committee and the Opposition Council asks him what experience he has had *in making railways;* whatever answer he makes it can only have practically one meaning, "none at all," and the Committee, having no confidence in the engineer, will throw out the Bill. We have, indeed, known of cases where, although the engineers have been men of mature experience, high abilities, and men well known in the Committee Rooms, the Bill has been thrown out because it happened to include *one* class of work with which the engineer was not familiar.

If the engineer is only fortunate enough to get hold of an unopposed line, of course it will go through, and having made that one satisfactorily, he will be able on future occasions to refer to it as "previous experience." This, however, is difficult to find, as even if all the landowners are favourable, some railway generally finds a *locus standi* from which to oppose.

When we come to consider that the great bulk of railway work is in the hands of old established engineers, as it necessarily must be, for commercial men and financiers will be unwilling to trust to inexperienced hands that upon which the success or failure of their projects will in a great measure turn — that is, the designing and construction of works which must be sufficiently strong and enduring to resist the wear and tear of work and weather, without an extravagant expenditure of money and material—it becomes evident that the emancipated pupil's wisest course is to endeavour

to obtain employment in the office of one of these engineers; there he will continue to gain experience and probably in a more serviceable way than during the period of his pupilage.

Feeling that he is paid for his work (is in fact no longer a school-boy) he will enter with more interest into it; and moreover, instead of selecting just what parts of the work he fancied, he must necessarily take up all details, and thus will gain a more perfect knowledge of the work as a whole, and if he acts up to his duties conscientiously, will form business habits of *punctuality*, without which, a man, no matter how talented, is worthless, for if you do not know when to expect him, his talents are not to be relied upon.

Beginning thus, he may, by diligence and perseverance, rise gradually into a secure and lucrative position in due time, but in this, as in other things, the ladder must be climbed rung by rung, the top is not to be reached at a bound.

There may be something made out by taking a small office and working for several larger engineers, if you can get the work, but they usually prefer having their work done in their own offices and under their own supervision, and this applies especially to Parliamentary work.

No doubt much reliance may be placed upon "influence" under certain circumstances, but, because a young engineer can command influence, it does not follow that he must certainly succeed, for it should be remembered that the older engineers not only command influence, but generally can also exert it to further their own views. In short, there is no road to success but by honest, plodding work, patiently persevered in, until opportunities occur which may be seized to improve the condition of the aspirant.

It is a matter much to be regretted, that in England, engineering is not made a profession proper (instead of a profession by courtesy) by compelling those who practice it, to hold diplomas, as in the medical profession, &c. It would be far safer for the public; for those to whom the designing of large works is entrusted, certainly hold in their hands great numbers of human lives, and it would certainly be more fair to the body of engineers themselves as, not permitting any to practice any particular branch unless they first pass a suitable examination, theoretical and practical; merit would be placed before money.

Nor would we stop at this, but extend the restriction to assistants, who should be required to qualify by passing an examination, in a manner analogous to that instituted in the case of chemists' and druggists' assistants.

[Concluded.]

IMPROVEMENTS IN PERMANENT WAY.

We give the following details of new systems of Permanent Way, which merit the attention of Railway Engineers. We are indebted to the inventor, Mr. J. W. Post, Permanent Way Engineer, Dutch State Railway Company. The trial lengths of iron permanent way laid in former years on different parts of system worked by the Dutch State Railway Company, are being extended this year by the addition of iron transverse sleepers, which attract notice chiefly from the simplicity of the fastenings.

The section of the ties is that of a plain trough as indicated in Fig. 1 (Plate CLII.).

The longitudinal section (Fig. 2) shows how the required tilt (1.20) is obtained by bending the sleeper up, the ends being curved down again and closed by pieces of angle iron, to give the sleeper a grip upon the ballast, so preventing end-shifting and the ballast from working out.

Some sleepers laid in sharp curves are provided with two more angle-irons in the middle, and so oppose much more resistance to shifting endways than timber ties.

At the rail joint (Fig. 3) the same sleepers are used as under the rest of the rails; thus all sleepers which have the same system of fastenings are identically punched.

Two different schemes of fastenings are used by way of comparison, both holding the rail directly on the sleeper, and both allowing to adapt this permanent way to all curves without difficulty and without necessitating the use of many different separate pieces.

In one scheme (Fig. 4) the clips are as simple as possible (rolled bar), and the bolts are provided with an eccentric neck, which enables to widen the gauge by 1, 2, 3, 4, 5, 6, 7 or 8 lines, by giving the bolts different positions; a mark on the top of the bolt indicates the position for laying and inspection. (Compare Figs. 5 and 8.)

This system has not been patented.

The second fastening system is shown in Fig. 6. Here the bolts are very simple (with ⊥ heads, which are passed through and turned round in the sleeper), and so is the clip (cut from a rolled bar), whilst the widening of the gauge in curves (1, 2, 3, 4, 5, 6, 7, or 8 lines) is obtained by different positions of fitting-pieces (Roth and Schueler's patent), provided with an eccentric bolthole. (Compare Fig. 7.)

The nuts of both systems have the same dimensions as those of the fish-plate bolts, and so the same spanner fits to all the nuts of the permanent way.

For laying the track the men use diagrams (Fig. 8), which are found to answer remarkably well, all mistakes being obviated.

The iron transverse sleepers laid in former years caused some trouble by the nuts of the fastenings working loose, constant attention being required to retain the bolts fast. Moreover, as the nuts had to be under constant supervision the sleepers could not be covered over with ballast, and did not lay steadily.

To overcome these objections, the nuts have since been secured by the same sort of steel split spring washers as had since a couple of years been applied to the fishbolts, and which avoid much expense in maintenance, holding the nuts capitally.

By way of comparison, Ibbotson's steel spring lock-nuts have lately been used on some 4000 sleepers, and till now proved effective.

The sleepers in question are being severely tested, being laid in sharp curves and steep gradients, and carry the whole of the main line traffic; they have till now given great satisfaction.

The Company is not yet able to judge of the relative expenses in maintenance (which, however, greatly depend upon the ballast) of iron and timber sleepers, as the statistics of hours of manual labour on the different devices of permanent way can only be compared over several years taken together; but the high prices of timber, together with the improvements made in the manufacture of iron and steel transverse sleepers and fastenings, more and more justify, from an economical point of view, the attempts made by the Dutch State Railway Company to reduce the cost of renewal by the use of wrought iron or steel as a material for permanent way.

The weight of the sleepers varies from 88 lbs. to 110 lbs.

The prices paid this year are:—

	£	s.	d.
Sleepers, per English ton, in the works ...	6	18	2
Eccentric bolts, with clips, per English ton, in the works	13	4	2
Clips and bolts, with eccentric fitting pieces, per English ton, in the works	13	4	2
Steel split spring washers per 1,000 pieces, free in the stations	0	18	4
Ibbotson's bolts and nuts, per English ton, free in the stations	24	7	8

LIGHT RAILWAYS.

(*Continued from page* 126.)

M. G. THOMAS' STEAM CARRIAGE.

We are indebted to the *Revue Générale des Chemins de Fer* for the following description of this carriage:—

The object of the inventor in the construction of this steam carriage was to diminish the more important expenses incurred in the transport of passengers at a slow speed. We can, indeed, for a local traffic, in which there is a large field for economical working, arrive at a most satisfactory result with this carriage by proportioning better the dead weight to be drawn to the number of passengers carried. This carriage supplies in itself the place of a complete train composed of locomotive, tender, luggage-van, and the different class carriages; it can also be brought into service for light goods traffic. The power of the carriages differ according to the nature of the line to be worked. That represented at Plate CLII. is very powerful, and has run for several months on lines of very steep gradients, accomplishing the service of a complete train. The carriage has three axles, and weighs in service from 23.5 to 24 tons. The engine can be easily and rapidly separated from the carriage proper, when needed for repairs. The former is fitted with a steam brake, whilst the latter has independent hand brakes. In certain carriages the engine compartment is entirely separate from the carriage, in which case the ends of each are furnished with buffers and drag-links. This arrangement may be useful for slow traffic, but with high speeds it is not advisable, as it is liable to occasion some dangerous oscillations. If the engine is one with the carriage, the rear axle should have free play in its boxes to ensure the safe passage round curves of short radii.

The principal dimensions of the carriage are:—

Total length of frame	40 ft.
,, height ,, ,, ...	15.75 ft.
,, width ,, ,, ...	10 ft.
Distance from forward axle to middle axle	9.83 ft.
,, middle axle to rear axle ...	14.1 ft.
Total distance between extreme axles...	23.93 ft.

The carriage contains on the platform level 20 places for first and second-class passengers, and a like number for third, and in its upper storey which is a sufficient height

for standing about 38 or 40 places; the entrance for first and second-class passengers is quite separate from that of the third. Furthermore the ends of the carriage can be made to supply about 20 places, so that the carriage can easily contain one hundred persons. It also has a separate luggage compartment having a capacity of 194.5 cubic ft., letter-boxes, tool chests, &c. Both the upper and lower compartments are heated by steam, and well ventilated and lighted.

The distribution of the load is the following:—

Weight on driving axle when in service, 12 to 13.5 tons
„ „ each of the other axles of the carriage when fully occupied ... ... 9 to 9.5 tons.
Total weight of the steam carriage about 30 tons.

The engine has two cylinders, each of the diameters being 8.66 in. with a stroke of 13.1 in., the relation of the connecting rod to the crank being as 7 to 8. The driving-axle has four bearings upon which rests the frame of the carriage. The springs corresponding to the two end bearings are connected at their extremities by transverse levers having unequal arms, transmitting to the bearings unlike pressures. When running, each part of the engine can be easily seen, the more important being reached by a trap at the foot of the driver. In case of rupture of any of the parts a plate placed under the engine prevents them from falling on the road, and preserves the carriage from accident. The tractive force of the engine varies according to the speed and the nature of the lines as seen from the following table.

Speed, in miles, per hour.	Maximum tractive force on driving wheels.	Gross weight drawn.				
		On the level.	Incline 1 in 200.	Incline 1 in 100.	Incline 1 in 71.4	Incline 1 in 50.
	lbs.	tons.	tons.	tons.	tons.	tons.
13.64	2420	230	115	75	58	44
18.6	2200	180	95	64	50	39
27.9	1584	115	64	44	36	28
34.1	1386	75	47	34	—	—

With a speed of 34.1 miles per hour (270 revolutions per minute), we obtain a piston speed of 10.6 feet per second which does not appear excessive when compared with that of an express locomotive.

Speed of carriage fully loaded:—

On an incline 1 in 100=31 miles per hour.
„ „ „ 1 „ 71.4=24.8 „ „ „
„ „ „ 1 „ 50 =18.6 „ „ „

On slight gradients and with less speed the carriage can draw a certain number of wagons.

The boiler represented at Fig. *A* corresponds to an engine of about 100 h.p. It is placed transversely; its construction is very simple being an ordinary cylindrical boiler. Its principal dimensions are the following:—

Total length of boiler	9.2 ft.
Diameter of cylindrical body... ...	35.3 in.
Thickness of plates	.39 to .429 in.
Interior dimensions of fire-box	width 37.40 in. length 21.65 in. height 39.37 in.
Thickness of fire-plate	.39 in.
Thickness of copper-plate	.58 in.
Thickness of tube-plate	.97 in.
Maximum pressure of steam... ...	10 atmos.
Number of tubes	127
Exterior diameter of tubes	1.75 in.
Distance between tube-plates ...	66.92 in.
Grate area	5.56 sq. ft.
Direct heating surface	34.27 sq. ft.
Tubular heating surface...	108.76 sq. ft.
Total heating surface	143.03
Weight of boiler empty...	3.27 to 3.43 tons
Weight of water	2420 lbs.
Weight of boiler in service	4.31 to 4.5 tons
Capacity of fuel boxes	3.7 sq. ft. or 1100 lbs. coal
Total capacity of water tanks ...	25.7 sq. ft.

Results of Trials and Economy Realized by the Use of this Carriage.—The first carriage constructed and which is the subject of our illustration has been running on the Louis de Hesse Railway. The carriage, properly so-called, was constructed by the Société de Construction de Machines of Nuremberg, who brought it as a passenger carriage from Nuremberg to Esslingen to affix it to the engine constructed in the workshops of the latter town. The first trial trips were made on the State Railroad of Wurtemberg, from Esslingen to Cronstadt, and Fellbach, presenting gradients of 1 in 80, and from Esslingen to Stuttgart and Hessenberg in the direction of Freudenstadt, which has gradients of 1 in 50 and curves of 984.25 ft. radius.

After the satisfactory trials made by the Royal Commission of Railroads, the Commissioners authorized for this carriage a maximum speed of 24.8 miles an hour. The trials were made by the Commission on a line 120 miles in length, with a speed reaching to between 31 and 34 miles per hour. The consumption of coal, not reckoning 220 lbs. required to get up the fire, was 1045 lbs., that is to say, 8.7 lbs. per mile. In a remarkable trial made by the Assembly of Frankfort-on-Maine on a line 116.16 miles in length from Aschaffenburg to Erbach, the consumption of fuel was 7.4 lbs. per mile with a speed of 18.6 miles per hour. On a line of steep gradient of the Obenwald Railway, the consumption of fuel from starting has been from 9.5 to 12.4 lbs. per mile, comprising the lighting and stoppages. On part of the line of slight gradients the carriage consumed 7.1 lbs. per mile. If we compare these results with those of the trains running on the railroads of the German Railway Union, we should see from the statistics that the con-

sumption of fuel of the latter varies between 21.2 and 28.3 lbs. per mile for passenger trains; but the steam carriage with the same conditions only uses between 7 and 10 lbs. per mile, from which it results that by using this carriage we obtain a mean saving of 14 to 17 lbs. per mile.

To establish the different economical results attendant on the use of this carriage in comparison to an ordinary train M. G. Thomas considers a simple passenger train to be composed only of a locomotive tender, luggage van, and two carriages running at the ordinary speed of passenger trains. He allows an annual journey of 28,900 miles.

DIRECT SAVING.—1. *Consumption of fuel.* A saving of 14 to 17 lbs. per mile, which gives for £28,900 miles 396,000 to 495,00 lbs., at ·0583s. per lb.	£108 to £135.
2. *Consumption of Lubricants.* About ·00302s. to ·0096s. per axle-mile, which represents	£3·5 to £7·5.
3. *Repairing and renewing of rolling stock.*	
1st. For engine compartment ...	£101·25 to £146.
2nd. ,, Passenger compartment	£31·5 to £67·5.
4. *Train Attendants.* The steam-carriage requires only a driver, conductor, and brake-man; we thus dispense with the services of two men, which is represented by ...	£110 to £120.
INDIRECT SAVING. — 5. *Interest on capital for rolling-stock.* A steam-carriage costs about £1,375, while a small passenger train requires from £2,500 to £3,000. We thus save, in the purchase capital, £1,125 to £1,625, which, at an interest of 4 per cent. per annum, represents a difference of interest of	£45 to £65.
6. *Repairing permanent way.* Reckoning as cost of repairing permanent way at 1.1s. to 1.3s. per locomotive mile, it gives for the saving, by use of steam-carriage	£105 to £120.
We thus obtain for the total annual saving in the use of the steam-carriage	£504·25 to £661.

RAILWAY SIGNALLING.

INTERLOCKING POINTS AND SIGNALS.

(*Continued from page* 126.)

AT Figs. 241, 242, and 243 (Plate CLIII.), is illustrated a side sectional elevation, plan, and front sectional elevation, respectively, of Messrs. Saxby & Farmer's "Ground locking apparatus," especially suitable for out-door work at sidings or similar localities where cabins are not provided.

Very little description of its construction or operation will be necessary after the previous detailed explanations given of analogous systems.

A are revolving locking shafts, worked by the action of the levers in a similar manner to that already described with reference to Mr. J. Imray's method of interlocking. The sections show these locking shafts provided with projections, *a*, which pass in front of the conflicting levers in order to render them in-operative — the shafts being moved when free by the action of the levers against the inclined terminations, *b*, of the projections.

Figs. 244 and 245 illustrate Mr. F. Webb's interlocking apparatus, as extensively employed by the London and North-Western Railway, and manufactured at the Company's Works at Crewe.

This apparatus is in reality a combination of improvements designed from time to time by the above-named gentleman.

The first apparatus of Mr. Webb's employed on this line was on the "catch rod actuation system"—that is the system in which the locking is effected by means of the preliminary movement of the spring catch-rod handles.

The advantage of this method of operation was, however, not found to adequately compensate for the additional parts necessary to change the reciprocating motion of these handles to the continuous motion required for the locking bars, and it was, therefore, soon abandoned for a simple "lever actuation."

Accordingly, Mr. Webb devised an apparatus in 1876, in which the necessary movement was obtained by the tilting of a tumbler or weigh-beam, having its fulcrum on the levers. These tumblers hook over square studs cast on the main framing when the levers are in their normal position.

The fulcra of the weigh-beams are very little above the level of these studs on the frame, and consequently a movement of $\frac{1}{32}$ of an inch of the hand levers is sufficient to impart the necessary movement to the locking bars. By

this arrangement a very prompt action is achieved with remarkably little strain upon the working parts.

The locking bars used in this apparatus are of channel-section rolled iron, which form gives great facility for attaching the locking studs thereto. These bars are also very accessibly arranged, and capable of being easily separated and removed without unnecessarily disturbing any other portion of the apparatus.

For the most part, the apparatus is constructed of wrought iron or steel, and great attention has been given to provide large contact surfaces to obviate undue local wear.

The shape of the catch-rod handles is peculiar to this apparatus, being "bow" shaped, but exceedingly convenient and comfortable to use.

The size of the apparatus or frames in use on this line vary from 4 or 5 levers to 144 levers, the latter being the largest one of the Company, and erected at Crewe. Many frames of from 50 to 120 levers have been erected at some of the principal stations, and many larger are in immediate prospect.

Each frame before leaving the shops at Crewe is completely erected, and the accuracy of the locking carefully tested.

A smaller interlocking apparatus of special design is also used by this company for working the points and signals of outlying sidings. These frames are erected in brick pits at the rail level, and constructed in a very simple but substantial manner, in order to withstand inclemency of weather to which they are subjected.

The larger and principal apparatus is represented in the figures of the drawings before referred to, in which *f* is the wood or other framing or foundation to which the quadrants, *g*, for the levers are attached; *h* is a fulcrum (partly of cast-iron) for the lever handle, formed so as to have a wrought-iron arm or tail secured to it, in order to carry the joints of two links, h^1, which are also jointed to the lever handle, h^2, so that the handle can move up and down in the arc shown by the dotted lines. To the cast-iron fulcrum part, *h*, the lower end of a rod, h^3, is jointed, which passes in front of the lever handle, h^2, while its upper end carries the fulcrum of the catch handle, h^4, which is jointed to the upper part of the lever handle, h^2. By depressing the catch lever, h^4, the lever handle, h^2, is lifted from the notch in the quadrant, and can be pulled or pushed over, the weight of the lever handle, h^2, acting to bring down the catch, h^5, (which may be formed solid with the lever handle) into the notch in the quadrant. To a projection from the lever handle one end of an adjustable link, *i*, is connected, the other end of which is jointed with a lever, i^1, having its fulcrum stud upon the cast-iron fulcrum part, *h*, of the lever handle; this lever, i^1, acts upon the notched bar, *j*, so as to effect the locking of the reciprocating channel section locking bars, I.

Fig. 245 represents a side detail view, illustrating the method of forming double notched bars.

At Fig. 246 is shown a portion of an interlocking apparatus as employed by the Great Western Railway, being designed and manufactured by their own engineers.

In this arrangement the levers operate a twist bar, A, at the end of which is a short arm or crank, which drives a countershaft below, by means of a connecting rod. The countershaft drives a locking bar or frame, F, by means of a small pinion, *p*, gearing into a rack fixed on the former.

To these reciprocating locking bars or frame, locks L, are secured by screws in a convenient manner.

The twist bars, A, are all of the same length, and are arranged between the levers at the top of the frame.

The countershafts are arranged in different plans, so as to work clear of each other, while the twist bars can be reversed at will, according to the nature of the locking to be effected.

In the drawing, the countershafts, cranks, and connecting rods are omitted in order to prevent unnecessary confusion, while the pinions are shown direct upon the twist bar.

The rack and pinions are placed over or under the locking bars or frames, while the latter travels $\frac{7}{8}$ of an inch to the right or the left, according to circumstances. It will be now readily understood that when the lever 6 is pulled over, it locks levers 2 and 5, and releases 1, 3, and 4.

At Figs. 247, 248, and 249 is represented a side-elevation, plan, and detail view, respectively, of Messrs. Saxby & Farmer's most recent arrangement of interlocking apparatus, on their well-known system of the "spring catch-rod actuation." This form of frame is now most extensively used throughout the railway world both here and abroad, and affords an admirable example of the leading and recognised appliances in this department of railway engineering.

The principle of the "spring catch-rod actuation" with the rocker has been already explained, so that very little further description will be actually necessary to enable our readers to readily understand the construction and operation of this beautiful piece of mechanism in its latest form. A are spring catch-rods, working behind ordinary levers, B, which have blocks, *a*, at their extremities working in the slotted rockers, C, mounted on fulcra *c*, by which the preliminary movement of the catch-rod is caused to actuate the locking, as already explained in an earlier number of our publication. The vertical vibratory or reciprocating motion of the ends of these rockers (upon raising the catch-rod) is transmitted to the horizontal spindles, D, carried by a suitable framing, through the intervention of a universal pin-joint, E, connecting rod, *e*, and crank, F. Upon these spindles are fixed or formed flat grid-iron plates, G, which, when the levers are in the normal positions, all occupy a uniform horizontal plane,

but which upon moving the catch-rods are caused to partially revolve upon their axes, and so be tilted or canted up at an angle with the plane of their normal position by means of the connections and moving parts already referred to.

This arrangement of locking will be at once recognized to incorporate Mr. J. Imray's principle of effecting the locking action by an angular or radial movement of a rocking shaft or its equivalent. The grid-iron plates referred to in the present frame is a very convenient and practical modification of the above-mentioned system of locking, they being in reality sections of "Imray's Rockers," while all their hitherto inaccessible parts are moved and cleverly re-arranged,

Horizontal reciprocating locking bars, H, are provided above or below these grid-iron plates, or both, according to convenience and extent of locking to be achieved, and upon which are fixed at suitable intermediate positions the locks or stops, *h*. The position of these locks upon the bars necessarily vary according to the nature of locking to be effected. These locking bars derive their reciprocating motion from certain of the spindles, D, which are provided with auxiliary links or connections, *d*, engaging between two projections or pieces, d^1, fixed on the bars for such purpose. So, that upon imparting motion to these spindles by the movement of the rockers, they are caused to transmit their motion to the horizontal locking-bars, H. Thus, upon moving a certain lever, one of these bars is caused to travel in a horizontal direction across the frame, so that the locks, *h*, fixed thereon at suitable and predetermined positions, are caused to move over and hold down certain grid-iron plates in connection with conflicting levers, whereby any inadvertent working at variance to safety is effectually prevented. The normal or "forward" lock upon conflicting levers is caused by certain of the locks, *h*, being moved over certain of the grid-iron plates (see position 1) whereby they are retained or held down in their horizontal position as shown. In this manner it will be readily seen that it is rendered impossible to effect improper movements of the levers, because the catch rods cannot be raised out of the notches in the fixed quadrants, while the rockers and their connections are held fast by the obstruction afforded to the revolution of the spindles carrying the grid-iron locking plates. When the locks, *h*, are moved from over any of the grid-iron plates, the catch rods and levers are free to be operated or pulled over in the frame, to work the points or signals connected therewith.

Supposing the point lever to have been pulled back, and the points set for the branch line, this will throw the locking rod into the second position (Fig. 249), locking the main signal, and freeing the branch signal. Then pulling over the branch signal lever, back locks the point lever, as the grid-iron connected to the former, on being thus canted, receives into one of its apertures, the projecting toe of the lock over it, and thus prevents its being moved while the signal is lowered.

It will now be understood that whenever the spring catch rods are raised, the spindles and grid-iron plates are likewise moved, a very small amount of motion being only required to cant up the latter so as to effect the necessary locking. The spindles D, and rockers C, have alike extreme positions of operation, that is, when the grid-iron plates on the spindles are in their horizontal position, the rockers are depressed forward; and conversely when the former are canted up, the latter are depressed backwards about their fulcra.

During any intermediate position of the rockers the locks are not released. In this manner the operator is necessarily obliged to complete any commenced movement of the levers before he can gain the required release of others in the system, which is obviously a great desideratum, and admirably attained in this ingenious type of apparatus.

At Fig. 250 (Plate CLIV.) we give a diagrammatic plan of the Signalling arrangements of the Central Station of Newcastle-on-Tyne—N. E. Railway.

There are several junctions and important stations on this line where a large number of levers are concentrated, principally on Steven's system, and of which perhaps the above is the best example.

Upon referring to the plan, it will be seen that there are 10 platforms at this station. The signals for controlling the traffic to and from the same are under the management of 4 boxes, viz.:—A, B, C, and D. The points and signals *b*, are worked from B box, those *c*, from C, and those *d*, from D, while *a*, are actuated from A box, which is the "major key" to the other three boxes, and which is situated in the centre of the main platform, immediately under the supervision of the station master or his deputies. From this controlling box all trains are started from, or received into the station, by means of an arrangement of levers fixed in a horizontal position, the turning of which to either the right or left hand form definite contacts with electric indicators. There is one such indicator provided for each platform, and which are placed in a convenient position within the boxes. According to whether the needles of such instruments are deflected to the right or left, the signals for "arrival or departure" to or from a certain platform, are given. Thus assume, No. 1 platform indicator has its needle deflected to the right hand, it denotes that a train is ready to leave No. 1 platform, and the out-door signals are actuated accordingly.

The converse action of the instruments signifies the "in coming" of trains.

The indicators work through B to C box, to call the requisite attention to the conditions of traffic, and there is a bell in electrical communication with A and B, C and D, &c., to announce the departure of trains, whereupon the signalman looks at his indicator, to learn from what platform a certain train is going to start, and subsequently sets his points and signals accordingly. In like manner the signalman in B, C, or D box, on being advised of the

arrival of a train, rings on to A box, and the signalman in that box indicates in return into which platform the train has to run.

The distance from A to B box is 148 yards; from B to C, 125 yards; and from A to D, 242 yards. In C box there are 80 levers, and in B box 42 levers; the levers in these two boxes being so interlocked by wire connections from one frame to the other, that they are controlled the same as if they were concentrated in one box. This distant interlocking is achieved by means of slotted plates fixed in a special frame at the ends of each apparatus, which operate a horizontal bar on which is arranged the "hook locking," as formerly emyloyed by Messrs. Stevens & Sons. The wire connections to these plates are attached to levers concerned with B or C box, and actuated by a balance-weight. Two inches movement of a lever in either box effects the necessary interlocking action, the same as if all the levers were concentrated in one frame.

There are three through platforms out of the ten shown on the plan, so that trains may arrive from opposite ends into the same platform. Accordingly, by the arrangements at A box, if the signalman gives the "arrival" signal to D box, for any of these three platforms, his levers working the electrical indicators are so interlocked that he cannot give the "arrival" signal to B or C at the same time. *(To be continued.)*

LIFE AND AGE OF A TELEGRAPH POLE.

THE Journal of the Telegraphs of America gives us some particulars of the life of telegraph poles in the United States. This subject may seem of trivial account to the great mass of business people, but when it is proved to them that it actually affects the cost and convenience of telegraph messages and dividends to stockholders, an interest may be awakened that will make the inquiry on the subject one of unusual interest, inasmuch as it affects the high or low price of rates for messages. The original cost of the erection of telegraph lines is important, but not so important in a series of thirty or forty years as is that of its maintenance in working order during that period. Some of the lines now owned and used by the Western Union Telegraph Company were first built more than forty years ago. When one is told that they have been built three or four times since that at great expense, it would seem to lead to the conclusion that a large amount of capital is necessary to represent the actual cost of the telegraph lines which have been in existence for many years.

The size of a telegraph pole has much to do with the duty which it is expected to do—that is, the number of wires it is calculated to carry. Many telegraph companies now owned by the Western Union Telegraph Company of to-day were organized and their lines built many years ago, before the organization of the "N. Y. and Mississippi Valley Printing Telegraph Company" in 1851, its name being changed to that of the "Western Union Telegraph Company" in 1856 by an act of the legislature of New York State.

The contract to build the original line required that the post be not less than thirty feet long, and twenty-seven inches or more in circumference four and a half feet from the butt, and twelve inches in circumference at the top, and set in the ground five feet. There were to be at least thirty of these posts to the mile, and they were to carry two lines of iron wire, one of which should weigh not less than six hundred pounds to the mile, and the other not less than four hundred and fifty pounds to the mile. These posts were to be of the best and most durable timber obtainable along the route they were to be stationed. The posts were intended for light lines only. When it was found necessary to increase the number of wires it was found to be necessary to have larger and more heavy poles, not necessarily much taller only in cities and large towns.

When considered apart from any local catastrophe or universal storm, the poles which were cut in winter were found to last as follows, according to the wood used, without being renewed: Cedar, 16 years; chestnut, 13 years; these are used in the Eastern, Middle and Western States. Juniper and cypress are used in the Southern States, and redwood is used in California. Spruce lasts seven years and juniper 13 years. If poles are cut in the summer their life will be about five years shorter than if cut in the winter. The soil in which they are set, and also the atmosphere and sunlight, have much to do with their life, for if one breaks off at the surface of the ground, or near the surface, as is usually the case, it will be five feet or more shorter than the others, and hence it is generally regarded as unfit to reset, and a new one must take its place. In some location this is provided for by having all the poles long enough to reset if they are sound enough for it to be economical to do so. The average period of the usefulness of a pole under ordinary circumstances is as above-mentioned. It is seldom that mixed woods are used on a line; they are all of one kind of wood.

The maintenance in working order of a telegraph line is of continual expense to provide for the wear and tear incidental thereto; the same as is the case with railroad lines, where it is always calculated that there are to be a certain proportion of new ties, rails, &c., every year, and it is charged to the maintenance account and reckoned as part of the cost of running the road.

(*Continued from page* 129.)

APPENDIX II.—(*continued.*)

1	2	3	4	5	6	7	8	9	10	11	12	13
No. of Piece.	Makers.	Application.	Year made.	Modulus of Elasticity. Kg. per sq. mm.	Limit of Elasticity. Kg. per sq. cm.	Breaking strength Kg. per sq. cm.	Contraction of Area per cent.	Elongation in 25 cm. (10 in.) per cent.	Analysis. Carbon per cent.	Sulphur per cent.	Phosph- per cent.	Remarks.
11b	Wurtemb Mining Office, Wasseralfingen.	Ordinary flats. 19 by 12 mm.	1876	2 142 000	1440	3610	41	13 5				Flat test piece. Soft in working. Very fine fibre.
144a	Baron Rothschild's Iron Wks., Witkowitz.	Rounds for machines.	1876	—	—	3650	13	8.6				Partly coarse crystal, partly grain, partly fibre; much cracked outside.
144b	ditto	ditto	1876	—	—	3920	13	10 8				As last.
142a	ditto	Lattice-iron for machines	1876	2 142 000	1090	3670	23	—				One-third coarse crystal, rest fibre, with crystalline spots; and one yellowish white spot.
142b	ditto	ditto	1876	2 060 000	1220	3770	23	19.9				Dark short fibre, some crystalline spots, and one nest of coarse crystal. Outside rough, but little cracked.
140a	ditto	Flats for machines, 52 by 20 mm.	1876	2 197 000	2120	3640	49	—				Flat test piece. Very fine fibre, light and dark grey mixed irregularly.
140b	ditto	ditto	1876	2 178 000	2030	3570	48.5	26.2				Ditto. Very fine fibre.
		D.—BOILER PLATE. (Flat Test Pieces.)										
125a	Bicheroux & Sons Duisburg.	Loco. boiler 10 mm. tested lengthwise.	1873	2 007 000	1020	3060	6.5	—		0.04	0.275	Very dark grey fine fibre, with a few small crystalline spots.
125b	ditto	ditto	1873	2 062 000	850	2740	5	1.5				Fine layers, dark, with a blue and yellow band going obliquely across
125c	ditto	do. crosswise	1873	2 174 000	1470	2880	5.5	—				Light and dark grey fibre, rough and short, with some crystalline spots.
125d	ditto	ditto	1873	2 118 000	1330	3020	5.5	2.9				Short and light fibre, flattened out.
125e	ditto	do. lngthwse.	1873	—	—	—	—	—				Bent cold to 32° hot to 64°
125f	ditto	ditto	1873	—	—	—	—	—				,, 34° ,, 69°
125g	ditto	do. crosswise	—	—	—	—	—	—				,, 13° ,, 56°
125h	ditto	ditto	—	—	—	—	—	—				,, 14° ,, 56°
41a	A. Borsig, Berlin	Boiler plate, 16 mm. lengthwise,	1876	1 932 000	1650	4100	24	—		0.01	0.093	Fine light grey fracture. Some dark layers. Arsenic.
41b	ditto	ditto	1876	2 181 000	1520	4400	23.5	11.6				As last. Much cracked outside.
41c	ditto	do. crosswise	1876	2 097 000	1130	3660	5	—				Rough fracture, in distinct light and dark grey layers.
41d	ditto	ditto	1876	2 113 000	1360	3960	12	7.3				As last. Numerous crystalline points at outside. Outside cracked. (The four pieces above had been straightened by hammering).
41e	ditto	do, lngthwse.	1876	—	—	—	—	—				Bent cold to 40° hot to 87°
41f	ditto	ditto	1876	—	—	—	—	—				,, 40° ,, 95°
41g	ditto	do. crosswise	1876	—	—	—	—	—				,, 15° ,, 66°
41h	ditto	ditto	1876	—	—	—	—	—				,, 10° ,, 48°
42a	ditto	Boiler plate, 14 mm. lengthwise,	1864	—	—	3810	10	6.1				Rejected for external honeycomb. Fibre in fine layers, light and dark in streaks.
42b	ditto	ditto	1864	—	—	3690	14	6.0				Ditto. As last. A second fracture near the neck.
42c	ditto	do. crosswise	1864	—	—	3560	5	2.6				Ditto. As above, but much rougher.
42d	ditto	ditto	1864	—	—	3720	—	3.6				Ditto. As above. Broke in neck, above the 25 cm. mark

1	2	3	4	5	6	7	8	9	10	11	12	13
No. of Pieces.	Makers.	Application.	Year made.	Modulus of Elasticity. Kg. per sq. mm.	Limit of Elasticity. Kg. per sq. cm.	Breaking strength. Kg. per sq. cm.	Contraction of Area per cent.	Elongation in 25 cm. (10 in.) per cent.	Anaylsis. Carbon per cent.	Sulphur per cent.	Phosph. per cent.	Remarks.
42e	A. Borsig, Berlin.	Boiler Plate 14 mm. Lengthwise.	1864	—	—	—	—	—				Rejected for external honeycomb. Bent cold to 29°, hot to 73°
42f	ditto	ditto	1864	—	—	—	—	—				,, 23° ,, 95°
42g	ditto	Do. Cross-wise.	1864	—	—	—	—	—				,, 10° ,, 85° slight cracks.
42h	ditto	ditto	1864	—	—	—	—	—				,, 11° ,, 92° slight cracks.
134a	ditto	Do. 12mm. Lengthwise.	1876	—	—	3710	34	13.6				Very fine, but short fibre.
134b	ditto	ditto	1876	—	—	3840	30	15.6				Similar.
134c	ditto	Ditto Cross-wise.	1876	—	—	3780	25	9.7				Similar, but somewhat rougher.
134d	ditto	ditto	1876	—	—	3730	27	14.6				Similar.
134e	ditto	Do. Length-wise.	1876	—	—	—	—	—				Bent cold to 53°, hot to 91° cracks.
134f	ditto	Do. Length-wise.	1876	—	—	—	—	—				,, 46° ,, 108° no crack.
134g	ditto	Do. Cross-wise.	1876	—	—	—	—	—				,, 27° ,, 105° cracks.
134h	ditto	Do. Cross-wise.	1876	—	—	—	—	—				,, 28° ,, 84° cracks.
67a	Borsigwerk, Upper Silesia.	Loco. Boiler 15 mm. Lengthwise.	1877	—	—	—	—	—				,, 41° ,, 95° no crack.
67b	ditto	ditto	1877	—	—	—	—	—				,, 44° ,, 95° no crack.
67c	ditto	Do. Cross-wise.	1877	—	—	—	—	—				,, 24° ,, 72°
67d	ditto	ditto	1877	—	—	—	—	—				,, 17° ,, 58°
131a	L. Fr. Buderus Neuwied.	Best-best Charcl. Boilr. Plate 13mm. Lengthwise.	1877	2 110 000	1550	3700	16	—				Light and dark grey, in layers, short rough fibre, outside cracked.
131b	ditto	ditto	1877	—	—	3550	17	11.2				Similar.
131c	ditto	Do. Cross-wise.	1877	2 020 000	1310	3180	4	—				In thick layers, rough outside, flaky.
131d	ditto	ditto	1877	—	—	3440	11	4.4				Similar.
131e	ditto	Do. Length-wise.	1877	—	—	—	—	—				Bent cold to 62°, hot to cracks 93°
131f	ditto	ditto	1877	—	—	—	—	—				,, 35° ,, 76°
131g	ditto	Do. Cross-wise.	1877	—	—	—	—	—				,, 33° ,, 52°
131h	ditto	Do. Cross-wise.	1877	—	—	—	—	—				,, 39° ,, 53°
21a	Dillingen Forge	Charcl. Boilr. Plate 10mm. Lengthwise.	1877	2 207 000	1500	3630	7	—		0.02		Light and dark grey in very rough layers.
21b	ditto	Do. Length-wise.	1877	2 178 000	2060	3600	12	8.5				Exceedingly fine layers, with some fine crystalline spots.
21c	ditto	Do. Cross-wise.	1877	2 173 000	1740	3480	—	—				Uniform layers of light and dark grey, broke through neck.
21d	ditto	Do Cross-wise.	1877	—	—	3560	16	7.1				Exceedingly fine layers, with two small crystalline spots.
21e	ditto	Do. Cross-wise.	1877	—	—	—	—	—				Bent cold to 25°, hot to 95°, slight crack at corner.

1	2	3	4	5	6	7	8	9	10	11	12	13
No. of Piece.	Makers.	Application.	Year made.	Modulus of Elasticity. Kg. per sq. mm.	Limit of Elasticity. Kg. per sq. cm.	Breaking strength. Kg. per sq. cm.	Contraction of Area per cent.	Elongation in 25 cm. (10 in.) per cent.	Analysis. Carbon per cent.	Sulphur per cent.	Phosph. per cent.	Remarks.
21f	Dillingen Forge.	Charcoal boiler plate, 10 mm., lengthwise.	1877	—	—	—	—	—				Bent cold to 21°, hot to 94°, decided cracks.
21g	ditto	ditto, cross-wise	1877	—	—	—	—	—				Bent cold to 52°, hot to 98°, no crack.
21h	ditto	ditto	1877	—	—	—	—	—				Bent cold to 40°, hot to 74°, cracked.
22a	ditto	ditto, length-wise	1877	2 166 000	1820	3490	10	—				Light and dark grey fibre in rough layers, broad crystalline band, and badly welded line.
22b	ditto	ditto	1877	2 122 000	1940	3490	12	8.7				Exceedingly fine layers, light and dark grey, with crystalline streaks at edge, and an unwelded line.
22c	ditto	ditto, cross-wise	1877	2 149 000	1880	3550	18	—				Light and dark grey in layers.
22d	ditto	ditto	1877	2 080 000	1870	3330	13	7.5				Very fine layers, light and dark grey, with some crystalline spots and several divisions. Broke outside the 25 cm. length.
22e	ditto	ditto, length-wise	1877	—	—	—	—	—				Bent cold to 21°, hot to 83°.
22f	ditto	ditto	1877	—	—	—	—	—				Bent cold to 22°, hot to 91°.
22g	ditto	ditto, cross-wise	1877	—	—	—	—	—				Bent cold to 29°, hot to 73°.
22h	ditto	ditto	1877	—	—	—	—	—				Bent cold to 27°, hot to 82°.
23a	ditto	ditto, length-wise	1877	—	—	3660	17	13.0				Very fine layers not well closed. Light and dark streaks, with some crystalline points. Broke outside 25 cm. length.
23b	ditto	ditto	1877	2 112 000	1640	3620	17	12.0				Fracture as last. Broke through end of 25 cm. length.
23c	ditto	ditto, cross-wise	1877	—	—	3440	—	5.0				Rough and dark; some crystalline spots. Broke in neck.
23d	ditto	ditto	1877	2 190 000	1970	3260	9	5.0				Similar to a and b, with little crystal. Broke outside 25 cm. length.
23e	ditto	ditto, length-wise	1877	—	—	—	—	—				Bent cold to 23°, hot to 95°, no crack.
23f	ditto	ditto	1877	—	—	—	—	—				Bent cold to 41°, hot to 84°.
23g	ditto	ditto, cross-wise	1877	—	—	—	—	—				Bent cold to 15°, hot to 71°.
23h	ditto	ditto	1877	—	—	—	—	—				Bent cold to 13°, hot to 73°.
120a	Hanoverian Machine Co., late G. Egestorff	Boiler plate, lengthwise.	1863	2 039 000	1210	3790	9	—				This and next from a boiler, which had run 330,000 km. at 9 atm. pressure. Test piece much honeycombed one side. Light and dark grey fibre, fine in thick layers; some crystalline spots.
120b	ditto	ditto, length-wise	1863	—	—	3500	13	3.0				Fine layers with one small crystalline spot.
18a	Friedr-Wilhelms-Hütte, Troisdorf.	Charcoal tender plates, lengthwise.	1877	2 120 000	1570	3380	14	—		0.005		Fine fibre, thick layers.
18b	ditto	ditto	1877	2 097 000	1530	3450	9.5	7.7				Very fine layers, with gaping unwelded division.
18c	ditto	ditto, cross-wise	1877	2 279 000	1760	2980	4	—				As a, but rougher.
18d	ditto	ditto	1877	2 238 009	1280	2680	0	0.8				As c, with unwelded division similar to b.
18e	ditto	Tender plates 9 mm., lengthwise.	1877	—	—	—	—	—				Bent cold to 35°, hot to 99°.
18f	ditto	ditto	1877	—	—	—	—	—				Bent cold to 26°, hot to 69°.

1	2	3	4	5	6	7	8	9	10	11	12	13
No. of Piece.	Makers.	Application.	Year made.	Modulus of Elasticity. Kg. per sq. mm.	Limit of Elasticity. Kg. per sq. cm.	Breaking strength Kg. per sq. cm.	Contraction of Area per cent.	Elongation in 25 cm. (10 in.) per cent.	Analysis. Carbon per cent.	Sulphur per cent	Phosph. per cent.	Remarks.
18g	Friedr. Wilhelms-Hütte, Troisdorf	Tender plates, 9 mm. crosswise	1877	—	—	—	—	—				Bent cold to 11°, hot to 67°.
18h	ditto	ditto	1877	—	—	—	—	—				Do. 12° do. 65°.
19a	ditto	Charcoal loco. boiler plates, 14 mm. lengthwise	1877	2 030 000	1490	3160	13			0 04 and 0.02	0 272	Fine layers, with many scattered sparkling points. Slight arsenic.
19b	ditto	ditto	1877	2 068 000	1410	2990	5	4.7				Very fine layers, dark, with crystalline streaks at edge, and black, unwelded crevice all across. Fracture much spread out.
19c	ditto	ditto, crosswise	1877	2 111 000	1320	2940	8					Fine fibre, in marked layers, with many scattered sparkling points, and large tracts of crystal.
19d	ditto	ditto	1877	2 029 000	1470	2880	2	1.3				Very similar throughout to 19b.
19e	ditto	ditto, lengthwise	1877	—	—	—	—	—				Bent cold to 16°, hot to 59°.
19f	ditto	ditto	1877	—	—	—	—	—				Do. 18° do. 68°.
19g	ditto	ditto, crosswise	1877	—	—	—	—	—				Do. 9° do. 41°.
19h	ditto	ditto	1877	—	—	—	—	—				Do. 9° do. 45°.
20a	ditto	Puddled loco. smokebox plates, 12 mm. lengthwise	1877	2 155 000	1530	3250	9			0.01		In very rough layers, with some glittering streaks.
20b	ditto	ditto	1877	2 047 000	1780	3310	—	4.5				Somewhat rough layers, light colour, with several thin crystalline streaks.
20c	ditto	ditto, crosswise	1877	2 060 000	1680	3550	15					Similar to 20a.
20d	ditto	ditto	1877	2 104 000	1570	4000	10	8.7				Similar to 20b, somewhat finer and darker.
20e	ditto	ditto, lengthwise	1877	—	—	—	—	—				Bent cold to 8°, hot to 72°.
20f	ditto	ditto	1877	—	—	—	—	—				Do. 14° do. 81°.
20g	ditto	ditto, crosswise	1877	—	—	—	—	—				Do. 30° do. 74°.
20h	ditto	ditto	1877	—	—	—	—	—				Do. 18° do. 70°.
66a	Grillo, Funke & Co., Schalke	Coke loco. boiler plates, 12 mm.	1877	—	—	—	—	—				Do. 39° do. 83°.
66b	ditto	ditto	1877	—	—	—	—	—				Do. 28° do. 73°.
118a	ditto	Lowmoor loco. boiler plates, 13 mm. lengthwise	1876	2 033 000	1300	4400	21					Fine fibre, light and dark grey, in sharp layers.
118b	ditto	ditto	1876	2 161 000	1970	4500	21	9.0				Very fine layers, light and dark, in streaks, large crystalline spots on one side.
118c	ditto	ditto, crosswise	1876	2 049 000	1390	4250	10.5					About two-thirds across crystalline, rest fibrous, in layers.
118d	ditto	ditto	1876	2 108 000	1050	4300	16.5	6.6				Very fine layers; light and dark, in streaks, some crystalline spots. Piece had been hammered, and was winding, hence stress not uniform.
119a	ditto	Charcoal loco. boiler plates, 12 mm. lengthwise	1876	—	—	4170	15	7.0				Very fine layers, light and dark in streaks.
119b	ditto	ditto	1876	—	—	4200	16	7.6				As last.
119c	ditto	ditto, crosswise	1876	—	—	4260	15	6.6				Somewhat rougher, with large crystalline spots.
119d	ditto	ditto	1876	—	—	4110	19	8.7				Similar, without the spots.

(*To be continued.*)

CORRESPONDENCE.

THE UTILIZATION FOR THE PUBLIC GOOD OF "THE RAILWAY STATION," AND ITS CONTIGUOUS PROPERTY, BOTH ECONOMICALLY AND SOCIALLY, IN EVERY CITY, TOWN AND VILLAGE OF THE UNITED KINGDOM.

To the Editor of the "RAILWAY ENGINEER."

SIR,—The time has arrived when the public and railway companies should cease to regard the railway station as simply and only a locality for the arrival and departure of passengers and luggage. The economic and social utilization of the railway station, guided by railway intelligence, enterprise and capital, initiates a most important epoch in our national railway progress, and reveals deservedly numerous, fresh and lucrative sources of permanent yearly revenue to railway companies. The comfort, convenience and social well-being of the inhabitants of all our cities and towns will be enormously promoted and increased; another important epoch in railway progress is imperatively at hand, which will enable railway companies not only to direct traffic as now, but actually in numerous localities to command it! Railway companies, guided by railway intelligence, enterprise and capital, must erect for the multitudes their Home Dwellings of the future!

Wherever needed, and in proximity to railway stations, both for the married and especially for the single, and built accordingly of Crystal Palace or Peabody magnitude accommodating under one roof from one to five thousand families or more—we allude to Harvey's Home Dwellings of Associated Homes, and similarly to Harvey's Associated Lodging Houses. The vast rentals of residents and tenants and their yearly traffic to and fro would add an enormous permanent yearly revenue to railway companies. These colossal home dwellings are the only perfect realization of our practical Christianity and of co-operative economy, are most urgently needed in all the numerous outskirts surrounding London and all other cities and towns in the United Kingdom, and in proximity to railway stations. Every village railway station, including Harvey's Village Aqueductal passenger railway stations, besides the village railway stations, co-operative stores most urgently needed in every village in the country, should contain the village railway reading room or club for men and boys, and a similar one for women and girls; and here we must direct the attention of railway companies to Harvey's Scheme of the People's Geographical Garden or cosmos, which, when known and understood, must, like the Crystal Palace, prove a lucrative source of yearly revenue to any railway company. Railway stations in London and in all our cities and towns should contain Harvey's most useful, appropriate, and inexpensive scheme of the Railway Registration Residence and Address Search Office, and similarly Harvey's Provincial Safe Deposit Institutions for the Safe Custody of Securities and Valuables of the Citizens and Townspeople; the Railway Station Repository for the Storage of Bulky Property and for Furniture; the Railway Station Lost Property Office for the City or Town; the Railway Station Lecture Hall for Hire. The following Railway Stations Reading Rooms, or Clubs—The Ladies, the Working Women's, the Domestic Servants, the Boys, and the Girls; the Railway Reading Room or Club for Gentlemen, and and another for Working Men, if a seaport town then one for the Sailors and Fishermen. Lastly, and not leastly, the Railway Station Co-operative stores, most urgently needed in every City and Town in the United Kingdom; the Railway Station Lost Property Office, &c.

Some ten years ago I published a leaflet strongly advocating the adoption of these most inexpensive and useful railways to connect one village with another, supported at wide intervals either upon iron pillars or upon strong wooden supports, sufficiently elevated so as not to interfere with the cultivation of the soil, striding over hill and dale as the crow flies; and the expense of the land being actually no more than the absolute space required for the iron pillars or wooden supports. A steam engine of small horse-power, even on a single line, amply sufficing for sparse populations.

I am, Sir, your obedient servant,

6, Cromwell Terrace, AUGUSTUS J. HARVEY.
Southtown, Great Yarmouth.

May 17th, 1882.

OFFICIAL REPORTS ON RECENT ACCIDENTS.

MAJOR MARINDIN has reported the result of his inquiry into the causes of a collision which occurred on the 25th December last, at Hornsey station, on the Great Northern Railway. There is abundant evidence to prove that the fog, during which this disastrous collision took place, was of a most exceptional character, both as regards the suddenness with which it arose and its extraordinary density between Finsbury Park and Hornsey. It seems to have commenced at Hornsey at 5.10 p.m., and to have at once become so thick that gas lamps upon the up platform could not be seen from the down platform, although two minutes previously the signal lamps in both directions had

been plainly visible. The fog bank then appears to have travelled southwards, and to have arrived at Finsbury Park down advanced starting signal at 5.25 or 5.26, just after the Moorgate train had passed No. 5 signal-box, and before it had reached the advanced starting-signal. At Finsbury Park also the weather had been sufficiently clear for all the signals to be seen up to the time at which the fog bank arrived. It may here be observed that if the fog had been either half a minute later or half a minute earlier at this place the collision would probably not have occurred, for, in the former case, the advanced starting-signal would not have been obscured when the Moorgate train came up to it, and the train would have been brought to a stand, while in the latter case this train would, in accordance with section 13 of the Block Telegraph Regulations, have been kept back at the platform, or at any rate stopped at the signal-box. As it happened, however, it was clear enough, when the platform starting-signal was lowered, for the signalman in box No. 5 to see his advance-starting signal, and he was therefore justified in allowing the train to go forward, and it was not until it had passed his box that, upon looking out, he saw that it had disappeared into the bank of fog, which had by that time hidden the advanced starting-signal from his view. The preceding train, the 4.23 p.m. down train from Victoria to Enfield, which had left Finsbury Park in tolerably clear weather, met the fog when about two-thirds of the way to Hornsey, and arrived at Hornsey at 5.24 p.m. in a fog so dense that the signals were quite invisible, and the tail lamps in the train could not be seen for over three or four yards. It waited there from 5.24 p.m. until the collision occurred at 5.30 p.m., on account of the line not having been cleared from Wood Green, the next block post in advance, where a down goods train, which had arrived upon the down slow line at 5.19 p.m., had been delayed in shunting, owing to the fracture of a coupling upon a trader's wagon, so that it was not clear of the main line until about the time at which the collision had occurred. The fog-signalman who had been on duty in the morning had been withdrawn at 11 a.m., and the station-master at Hornsey had, at 5.10 p.m , sent a porter for the platelayers whose duty it was to fog at the distant signals, and had told the signalman in the station signal-box to send his booking boy for a man named Borringer, whose duty it was to fog at the down home-signal. Unfortunately the signalman did not recognize the urgency of the case, and, instead of despatching the boy at once, he allowed him to complete some train telegraphing and booking operations, thus losing five minutes, which, as it turned out, were of inestimable value, for the man Borringer had actually arrived and was on his way back along the platform when the collision occurred, and would probably, if he had been summoned five minutes earlier, have been at his post in time to avert the catastrophe. The driver of the Moorgate train started from Finsbury Park at 5.25 p.m , four minutes late, found the starting signal, and the signal for the junction with the fast line off for him, and ran into a fog bank before arriving at the advanced starting-signal, which he never saw. This signal was at danger, but he took it for granted that it also was off for him, and he proceeded on this journey unable to see two yards before him, and so utterly lost that he did not know when he passed the Hornsey down distant and down home-signals, and only took steps to stop his train when he caught sight of the glimmer of a gas lamp at the south end of Hornsey down platform, within 45 yards of the other train. He then applied his brake, but, although it may have had some effect in mitigating the result of the collision so far as his own train was concerned, there was no time for it to do much in reducing the speed of the train, and the collision took place when he was still running at certainly not less than eight miles an hour. This driver states that he ran down to the Finsbury Park advanced starting-signal at a low rate of speed, prepared to stop if necessary, and that after passing it he went at a reduced rate of speed all the way to Hornsey, but, although he certainly did take about a minute more than the usual time in running the distance, his estimate of what "running at caution" means is evidently far too liberal, for, as he took only four minutes to run over 2,400 yards, he must at one period of the journey, when according to his own statement he could see "nothing off the engine," have been running at a speed of not less than 18 or 20 miles an hour. It is, therefore, clear that although this accident was a consequence of a very sudden and dense fog, yet that the driver of the Moorgate train is greatly to be blamed for it. He knew perfectly well, for he is accustomed to drive upon this line, that trains are very often brought forward by the lowering of the starting and slow line junction signals to the advanced starting-signal, and there kept standing until the station ahead is clear, and he ought, therefore, to have been prepared to find this signal at danger, and to stop at it. The only possible excuse for him is that he knew that, when there is a fog, trains are not allowed to go forward to this signal, but are kept back at the platform or opposite to the signal box, and he may therefore have thought that the signalman in No. 5 box would not have allowed him to start from the platform in this case, unless he had received "line clear" from Hornsey, and had taken off his advance starting signal. As, however, he met the fog bank advancing towards him after he had passed the signal box, he ought to have guessed that the fog was a sudden one, and ought not to have passed the advanced starting-signal, taking it for granted that it had been lowered for him, without ascertaining what was its actual state, which he might easily have done by stopping, and sending his fireman to find out, either by feeling the weight upon the signal post, or by enquiring at the signal box. Further than this, he ought, instead of running headlong through the fog, to have proceeded very cautiously in accordance with the rules. It

is impossible to avoid the conclusion that the signalman at Hornsey also contributed in some degree to this accident by his dilatoriness in obeying the order of the station-master to send for Borringer. He ought to have recognized the fact that the danger arising from so sudden a fog must be guarded against with as little delay as possible, and he might very well have sent his telegraph boy at once, taking up the work of booking trains himself. The lesson to be learnt from this fatal collision is that the whole system of fog signalling, in use generally throughout the kingdom, is a very weak point in railway working, and that the rules for working under the present system, weak as it is, require improvement. Even when fog signalmen are at their post, and are known by the drivers to be there, it must be remembered that in very thick fogs the fogman and his lamp are frequently invisible, and that therefore a driver does not get any *positive* intimation when a signal is off, such as he has when the signal lamp or arm is itself visible, but only a *negative* signal, on account of the non-explosion of two detonators, which may possibly have failed to explode, although upon the rail, and intended to do so. It is therefore evident that the rule enjoining "caution" when running in a fog should be rigidly enforced, and it might well be more explicit in laying down at what speed drivers are to run when approaching signals under such circumstances. But if the risk be appreciable at all times during fogs, it becomes far greater when the fog is a sudden one, for in such a case there must be, under the present system, an interval of time when the signals are not protected by any fog signalmen, and when under the existing rules, drivers, unaware whether the fog has been a sudden one or not, are in the position of not knowing, when they pass a signal without exploding a detonator, whether this is because the signal is off for them, and therefore no detonators have been placed upon the rails, or whether it is because no fog signalman has yet arrived at the post. It should in my opinion be clearly laid down that a driver is not to pass any signal during a fog without satisfying himself that it is off for him, either by the receipt of a hand-signal from the fog signalman, where he can see him, by a verbal intimation when the fog is so thick that neither the man nor his lamp are visible, or by actual inspection of the signal-post where there is no fog signalman at his post. Again, it is manifest that a train stopped at a station during a fog, before any fog signalmen are out, is, although nominally within the protection of fixed signals, in even a worse position than a train stopped in ordinary weather between two stations, for the tail lamps in the one case would be visible and in the other would not, and therefore, the rule that a train stopped outside fixed signals is to be protected by detonators, placed upon the rails a certain distance behind the train, should undoubtedly be made to apply to trains stopped within fixed signals, when such signals, being invisible, and unguarded by fog signalmen, are practically useless. If such a rule had been in operation the train at Hornsey would have been protected by fog signals, placed upon the rails by either the guard or the station staff, and the accident would not have occurred. No doubt such precautions as I have recommended would cause delay, but delay ought not under proper regulations, properly observed, to cause accidents, and any amount of delay would be preferable to the risk inseparable from the practice of running blindfold in a fog, which seems to be far too common at present. It is most desirable that some means should be devised by which drivers may be informed with certainty whether fog signalmen are or are not at their posts, and that where the signal arm and lamp are at any considerable distance from, or height above the line, a lower arm and strong reflecting lamp should be provided, as nearly as possible at the level of the driver's head. Even with this addition, however, cases will certainly arise in which the fog is so thick that the signal lamps are obscured, and therefore the advantages of a system of fog signals, mechanically controlled by the signalmen, and always available when wanted, to take the place of the present system of fog signalling by means of platelayers, often wearied and half frozen, is so apparent, that I am certain that any such system, found upon trial to be simple and reliable, would be very quickly adopted, and would add immensely to the safety of railway travelling. It is to be hoped that one result of this collision may be that a further trial may be given to some of the inventions already existing for the improvement of fog signalling, and that, if none of them be considered altogether satisfactory, the thoughts of many mechanical engineers may be turned to this subject, and the necessary additions elaborated. In conclusion, I would remark that such a signal as the Finsbury Park down advanced starting signal is of so great importance that it should not be left without a fog signalman, as I am informed is the case, although in this instance, owing to the suddenness of the fog, the man detailed for the post could not have been there in time to stop the Moorgate train, and so avert the accident.

Major Marindin has also reported the result of his inquiry into the causes of a collision which occurred on the 25th of November, 1881, near Tayport station, on the North British Railway. The evidence regarding the times at which the special goods train and the 5.5 p.m. passenger train respectively, left Leuchars junction and Old Leuchars, and the consequent interval of time which was maintained between these two trains, is somewhat conflicting, but, after allowing for the difference in the watches and clocks which were referred to, it would seem probable that the goods train, which, after arriving from Perth, is booked to run from Ladybank junction "as required," left that place at 5.40 p.m., arrived at Leuchars junction station at 6.35 p.m., started again at 6.38 p.m., arrived at Leuchars old station

at 6.40 p.m., and started for Tayport at 6.42 p.m., and that the 5.5 p.m. passenger train left Ladybank at 6.20 p.m. and Leuchars junction station at 6.52 p.m., passing Leuchars old station at about 6.54 p.m. The booked time for the passenger train is, from Ladybank at 6.10 p.m., and from Leuchars junction at 6.40 p.m., and it is therefore apparent that, after leaving Leuchars junction, the goods train was running in the time of the passenger train, but that it left Old Leuchars, 12 minutes before the passenger train passed. In all other respects, except the time, the evidence is clear enough, and leaves no doubt as to the circumstances under which this collision took place. When the goods train stopped near Tayport south cabin at about 6.53 p.m. or 6.55 p.m., with the rear brake-van about 105 yards north of the cabin, the usual shunting operations necessary to place this train in the goods yard on the east or up side of the line were commenced. The engine was detached, run ahead to a cross-over road worked from Tayport north cabin, crossed on to the up line, brought back to another cross-over road worked from the south cabin, again crossed on to the down line, and hooked on to the tail of its train, with the tender then in front. Without any delay, according to the evidence, the train was then started by signal from the guard only, with the intention that the engine should draw it across on to the up line, and then push it back into the goods yard. After running for about 25 yards, the driver discovered that, instead of going through the cross-over road, he was going along the down line, but, before he could quite stop his train, the passenger train, running probably at between 15 and 20 miles an hour, dashed into him, with the terrible consequences recorded above. The driver of the passenger train, after leaving Leuchars junction, found no signals against him until he came in sight of the Tayport south cabin down distant signal, which was at danger, and which does not appear to have been lowered until after he had passed it. He states that he reduced the speed of his train to about 10 miles an hour, but applied steam again on the south cabin down home-signal being lowered for him, just as he passed the distant-signal. He admits that the north cabin down distant-signal (the low arm on the south cabin down home-signal post) was at danger, but states that, upon coming in view of the north cabin down home-signal, when he had run about 120 yards past the south cabin down distant signal, he found this signal, and also the north cabin down starting-signal off for him. He therefore considered that he was justified in running forward into the station, and he passed the north cabin down distant-signal at a speed of about 15 miles an hour, shutting off steam about 30 yards further on, and coming into collision without having the least warning or suspicion of danger at a point 81 yards inside the south cabin down home-signal. There is no reason whatever to doubt the correctness of any part of this statement, except that the speed was probably more than 15 miles an hour, and that, according to the evidence, the north cabin down starting-signal was not lowered, but this fact does not in any way affect the case. It should here be remarked that the driver of the goods train saw the light on the approaching passenger train engine when it was still some considerable distance off, and that he had heard the whistling for the distant-signal just as he was starting his own train, but he took no steps to warn the driver of the passenger train, or the signalman, by sounding his whistle, because he thought the cross-over road was set for him to cross, the home-signal, therefore, necessarily locked at danger, and that the passenger train would certainly stop at this signal. It is perfectly clear that, when the signalman in the south cabin, Thomas Dippie, heard the passenger train whistling he forgot all about the goods trains, closed the cross-over road, and at once pulled off the down home-signal, so that the driver of the passenger train found all the signals clear for him except the north cabin down distant-signal. It is at first sight difficult to understand how signalman Dippie could have forgotten the goods train, the engine of which he had, only one, or, at the outside, two minutes before signalled back to its train through the cross-over road, knowing moreover, as he must have done, that the invariable practice was for such trains to be drawn across on to the up line through the same cross-over road before being backed into the goods yard; but, leaving for the moment out of consideration the fact that the goods engine was without the proper lights, showing in the direction of both the signal-cabin and the approaching passenger train, and that the tail and side lights on the goods brake-van were hidden by the engine, the evidence of the station-master at Tayport furnishes, I think, an explanation of his forgetfulness, for it is stated that this signalman had that day commenced his work soon after 6 a.m., that his daily tour of duty was, on Mondays and Fridays, from 6.20 a.m., and on other week days from 6.40 a.m., until after the arrival of the train *due* at 10.6 p.m., and on Sundays twice during the day to pass trains. At the time of the accident, therefore, he had been on duty for nearly 13 consecutive hours, while his daily work on week days, exclusive of the time he may have taken in walking to and from his home, would average over 15½ consecutive hours, even if the last train, the arrival of which he had to await, was punctual to the minute. It is hardly too much to say that it is a scandal that such an amount of work, as is implied by these hours, should be exacted from any man upon whose vigilance depends the safety of the public, and who by a momentary act of forgetfulness may, as in this case, cause a fatal catastrophe, and I was glad to learn that since the date of this accident an improvement in this respect has been made at Tayport. There are, however, others beside the signalman in Tayport south cabin who contributed to this accident, either by their carelessness or by

their disregard of the rules and regulations of the Company. If the lights on the engine had been reversed, according to rule, it is more than probable that signalman Dippie would have seen them, and would have kept his home-signal at danger, so bringing the passenger train to a stand before coming to the point of collision, and, even if he had failed to look for the lights, and had taken off the signal, the driver of the passenger train might have seen them from a point over 250 yards away, and almost to a certainty would have seen them in time to stop his train with the powerful brakes at his command. The driver of the goods train states that he ordered his fireman, who was one of the unfortunate victims of the collision, to reverse the lights, and that he thought this had been done; but, even if his statement be accepted as correct, he is not free from blame, for it is the duty of a driver, as it is of all men in such responsible positions, not to content themselves with simply giving an order, but to satisfy themselves that it is properly carried out. There can be no doubt, moreover, that the goods train ought to have been shunted at Leuchars old station; but the omission to do so cannot be charged against those responsible as an actual breach of rules, although it was certainly a grave error of judgment. According to the rules a goods train may be started within 10 minutes of the time at which a passenger train is due to leave, if it has been ascertained by telegraph or *otherwise* that the passenger train is late, and a sufficient margin of time is allowed for the goods train to reach the next shunting place in time to avoid delay to the passenger train. In this case, although there was no telegraphic information as to the running of the passenger train, yet the fact that the previous portion of the same train was late, and the knowledge that the St. Andrews branch train would be late, may be said to have justified the assumption—which was borne out by what actually occurred—that the 5.5 p.m. train would be over 10 minutes late. I do not, however, consider that a sufficient margin of time was given for the goods train to run the distance to Tayport, and to be shunted clear of the main line, considering the work which had to be done. The station staff at Leuchars did not necessarily know—and state that they did not know—the process of shunting goods trains into the goods yard at Tayport; but the guard of the goods train must have known about the time which would be occupied by this work, and he would have exercised a wise discretion if he had shunted his train at Old Leuchars. I cannot consider him entirely free from blame for not doing so, and for omitting to make inquiries as to the running of the passenger train, as he was bound by the rule to do. The porter at Old Leuchars was also in fault, if the statement of the driver of the goods train, to the effect that he told this man that he ought to shunt, is correct; but the truth of this statement is not admitted by the porter, and it varies considerably from that made by the guard of the goods train on the same head, so that it cannot be taken as being altogether beyond doubt. The station-master at Leuchars junction ought at any rate to have warned the driver of the passenger train of the precise time at which the goods train had started, for, although rule No. 128 leaves it to the discretion of the station-master whether a goods train may be despatched in front of a passenger train under certain circumstances, it positively enjoins that the driver of the passenger train is, upon arrival, to be warned. It is, however, improbable that in this case the omission to give the warning contributed in any way to the accident, for, running with the signals off and, apparently, a clear road, the driver of the passenger train would, on approaching Tayport, most likely have considered that the goods train had arrived in time to be shunted into the goods yard. I would here state that, although, according to the strict reading of the rules, it may be argued that the driver of the passenger train should, upon seeing the north-cabin down distant-signal at danger, have "reduced the speed of his train so as to be able to stop at the distant-signal post," and when he found the way was clear, have proceeded "slowly and cautiously within the distant-signal, having such control of his train as to be able to stop it short of any obstruction which may exist between the distant-signal post and the home-signal," yet the driver was, in my opinion, justified in this case in believing that the road was clear for him to run up to the platform of the station. There is no question but that the north-cabin down home-signal was off when he came within view of it, and as the distant-signal cannot be lowered unless the down starting-signal is lowered, and this latter signal is very properly ordered not to be lowered unless the staff used on the single line to Newport is in the Tayport signal-cabin, it must so frequently happen that the distant-signal is at danger, when the line is perfectly clear, that drivers are practically being educated to regard this signal simply as an indicator of the position of the starting-signal. At the same time, I do not consider that any train should, even when the home-signal is off, pass a distant-signal at danger, within 600 yards of what may, in some respects, be considered as a terminal station at so high a rate of speed as 20 miles an hour, whatever may be the amount of brake power with which it is provided. The best safeguard against such accidents as this, although recent experience has shown that it is by no means infallible in preventing the mistakes of signalmen, would be the adoption of the block telegraph system, for, under the rules for working this system upon those parts of the North British Railway where it is in use, the signalman at Tayport south cabin would not have been justified in giving permission for the passenger train to leave the preceding block post until the goods train had been shunted clear of the main line, and in order to have caused this accident he must have committed

two gross errors instead of one, that is, he must first have given "line clear" while the goods engine was actually crossing in front of his cabin, and then have lowered his signals after the engine had got to its train. I understand that during the past year the North British Railway Company have been introducing block telegraph working upon their main line between Edinburgh and Berwick, but the returns sent into the Board of Trade show that, even with this addition, they have hitherto done very little in this direction; and it is a fact that over the whole of their Fifeshire railways, subjected as they are in many places to a very heavy traffic, there is not one single mile of line worked upon the block system, except a few short lengths which have been recently constructed, and which would not have been passed for passenger traffic unless the necessary electrical instruments for this mode of working had been provided. Such a state of things as this, to say nothing of the absence of interlocking and the unsatisfactory condition of many of the stations upon these lines, should be impossible at the present time, and it is to be hoped will soon cease to exist, but in the meantime the greatest possible care should be taken that, in the absence of the protection afforded by block working, the strictest attention to the rules for preserving a proper interval between trains should be observed, and that the hours of work should be so regulated that the carrying out of these rules may not be entrusted to signalmen and others practically incapacitated by overwork. As it is stated that it is the *invariable* practice to draw back down goods trains through the cross-over road near Tayport south cabin, in order to get them on to the up line, and then into the goods yard, it is most desirable that a disc signal should be provided, working with or interlocked with the points, and that drivers should not be hand-signalled back, as at present.

Major-General Hutchinson has reported the result of his inquiry into the circumstances connected with the collision which occurred on the 23rd December last, between Parks Bridge Junction and St. John's station, on the South Eastern Railway. This collision, between an East London up passenger train and an up coal train, at a point about 205 yards outside St. John's main-line up home-signal, at which the coal train had been unnecessarily stopped, was caused by a mistake on the part either of Overall, the signalman at St. John's, or of Errill, the signalman at Parks Bridge Junction, the former denying that he had ever received or accepted any signal from Errill for the coal train, and the latter as confidently affirming that Overall had done so. The evidence, however, points to the fact that the mistake was made by Overall, whose signal, twice repeated, to Errill, for a down train, would hardly have been refused by the latter without proper cause; that cause being probably that the up needle was indicating "train on line" for the up coal train. Overall acknowledges that, instead of sending the signal a third time for the down train, he ought, in the first instance, to have used the speaking instrument for ascertaining why Errill had refused the two other signals. Overall appears, therefore, to have made two mistakes, by the avoidance of either of which there would probably have been no collision; viz., first, in forgetting that he had accepted the coal train, and secondly, in not using his speaking instrument when he could not get the signal for the down train accepted. The driver of the East London train can hardly have been keeping a good look out as he was approaching the coal train, or he might have seen it much farther off than the 25 yards which he states. It was certainly to be seen for at least 150 yards, and probably more; and in this distance, at a speed stated to have been about 25 miles an hour, with the prompt application of the brake power at his disposal, the speed might have been reduced more than it was, the driver stating it to have been still 20 miles an hour on collision. The brake arrangements on the train were, however, by no means satisfactory, the engine (belonging to the Brighton Company) being fitted with Westinghouse brake (in action), and the six carriages composing the train with the vacuum-brake arrangements, the latter being, of course, of no avail. Had the engine and train been fitted throughout with either the Westinghouse or vacuum brakes, the collision would probably have been altogether avoided, or its force greatly mitigated. This collision will not have been without its use if it leads to the brake-power on these East London trains being arranged on a satisfactory system, instead of the present highly unsatisfactory one. With regard to the block-telegraph instruments on this part (and I believe many other parts) of the South-Eastern Railway, it seems anything but desirable that, if by mistake a signalman uses the wrong plunger for announcing a down train, he thereby gives "line clear" for an up train, and *vice versâ*. On other one-wire systems there are separate plungers for announcing trains, which plungers have no effect on the positions of the needles or semaphores; and this plan seems much less likely to lead to mistake than the one in question. The position of the signal-cabin at St. John's is by no means good as regards up main-line trains, which, if stopped at the up home-signal, are nearly out of sight of the signalman. The cabin is at the up end of the platforms, nearly 300 yards from the main-line up home-signal, between which and the cabin there are an overbridge and curve. An additional cabin at the down end of the station would be a great advantage for the safe working of the traffic.

Colonel Yolland has reported the result of his inquiry into the circumstances connected with the accident which occurred on the night of the 28th January last, to an empty down coal train, and subsequent disastrous collision between

a portion of it and an up passenger train, between Old Ford and Bow stations on the Eastern Section of the North London Railway. From the statements it will be seen that as an empty down coal train, from Poplar station to Brent sidings, which consisted of an engine, 50 trucks, and two brake-vans at the tail of the train, was approaching Old Ford station, the rear half of the draw-bar of the 35th truck from the front, broke, and one end of it was drawn out of that truck and fell to the ground, the other end still remaining coupled to the front end of the draw-bar of the 36th truck, and the lower end of the draw-bar ran into the ballast, probed a sleeper, and threw the leading truck (the 36th) of the separated portion of the train, off the rails, dragged two or three trucks after it, and fouled the up line just as a passenger train was approaching that spot from Old Ford station. This passenger train was the 9.50 p.m. train from Broad Street to Poplar. It consisted of an eight-wheeled tank engine, with four wheels coupled and with four wheels on a bogie frame, running with the bunker head in front and chimney behind, 10 carriages and two brake-vans, one at each end, with a guard riding in it. The train was fitted with continuous sectional brakes, one half being under the control of the engine-driver, and the rear half under the control of the head guard of the train. It reached Old Ford station, about four minutes late, at 10.15 p.m., and after stopping there about one minute it proceeded on its way towards Poplar, and was travelling at about 10 or 11 miles an hour, when, without any warning whatever of anything being wrong, it ran into the truck of the coal train which had been thrown off the rails of the down line, by the after half of the draw-bar of the 35th truck having broken, been drawn out of the coal truck and dropped down on to the ballast, and was thus forced against a sleeper; and the truck was lifted and thrown off the rails, fouled the up line immediately in front of the passenger train, and was run into, about 10.19 or 10.20 p.m. The engine of the passenger train was thrown off the rails, broke one outside rail and bent two others, and after running somewhat less than 30 yards, came into violent contact with the north abutment of the Fairfield Road overbridge, and was thus suddenly arrested in its progress. The front part of the body of the brake-van next to the engine was broken and lifted up, while the framework ran under the buffers of the engine. The third-class carriage next to the brake-van had the front half of its body destroyed, and the end of the next carriage was also smashed. The driver of the coal train was not aware, at the moment when it occurred, that his train had separated into two parts; and if he had been, he could have done nothing to prevent the subsequent collision from taking place. I can see no want of care on the part of the Company's servants that led to this accident and the subsequent collision, and which caused the death of so many people and the serious injury to so many others. A faulty mode of construction of the coal truck caused this accident, which mode of construction had previously caused other accidents, some of them of a very serious character, though not precisely similar in all their details to this one. I annex drawings of the mode of construction of this truck, supplied to me by the officers of the North London Railway Company. The draw-bar of wrought iron in the 35th coal truck, was made up of two halves passing through the headstocks at the ends of the truck, and joined together at the centre of the truck and under it, by the ends being passed into a wrought-iron hollow sleeve with two cotter holes in it, and one in each end of the draw-bar under the iron sleeve, with a cotter passing through each. By this means the draw-bar was made continuous throughout its whole length of about 16 feet 4 inches. Besides these central cotters and cotter holes, another cotter hole was made in each half length of the draw-bar, which passed through a cast-iron circular washer with two cotter holes in it, one on each side of it, the washer being made to abut against a piece of india-rubber at the back of a wooden bar or beam, whose ends are morticed into the sides of the sole beams of the truck, and a cotter passed through the holes in the cast-iron washer, and in that of the draw-bar. This cast-iron washer, as well as the wrought-iron sleeper, both effectually covered up and concealed the sides of the cotter holes (four of them altogether in the two half draw-bars), and prevented any examiner from seeing whether there was anything wrong in the iron at the sides of the cotter holes of the draw-bar through which the cotters passed. In this accident the draw-bar broke in the cotter hole, 2 feet from the centre of the truck at the back of the wooden cross-bar, and 6 feet 2 inches from the outer end of the draw-bar. The long piece of the draw-bar was then drawn out of the 35th truck, and hung on by the double coupling chains to the front end of of the 36th truck, the other end dropped down (as shown in the drawing) into the ballast and against a sleeper, and thus forced the 36th truck off the rails whilst it was still in motion. This truck was then driven foul of the up line. The diameter of the draw-bar of wrought-iron is about $1\frac{5}{8}$ inches; the cotter hole in it is $2\frac{3}{8}$ inches long, $\frac{1}{2}$ an inch wide, and $1\frac{1}{2}$ inches deep. The failure of this draw-bar was evidently due to there having been a flaw running throughout the metal at one side of the cotter hole. This flaw could not be seen, as it was completely covered by the cast-iron washer. The iron in the draw-bar was also of inferior quality. The immediate effect of the cotter holes made in these draw-bars, is to reduce the strength to less than $\frac{2}{3}$ of the original bar, as far as a tensile strain is concerned; and when one of the sides fails, as in this case, owing to a flaw in the material, its ultimate strength is less than $\frac{1}{3}$ of the original strength of the draw-bar. According to the construction adopted in this 35th truck, which is by no means an unusual one, there are no less than four cotter holes in the draw-bars under the truck, and of course the chances of accident are increased by the

number of cotter holes. The truck belonged to the Metropolitan Railway Carriage and Wagon Company (Limited), had been hired by the Bedworth Coal and Iron Company, and had taken coal from the Charity Colliery, Bedworth, near Nuneaton, to J. and C. Harrison, Mark Lane, London. The tendency of late years has been to increase the number of continuous draw-bars under railway vehicles, but there have now been several instances in which these long draw-bars have broken, been drawn out of the truck, and then been the means of throwing it off the rails, and in some cases causing other trucks and carriages also to leave the rails, and to produce serious accidents, or, as in this particular case, to foul the other line of railway immediately in front of a train travelling in an opposite direction. It seems time that some effectual precaution should be introduced, without delay, that will prevent a repetition of these disasters. Thus, on the 3rd July, 1875, a very serious accident to a mixed goods and passenger train occurred on the Rothbury branch of the North British Railway, between Longwitten and Scots Gap stations, in which three passengers and the second guard of the train were killed, 10 passengers were reported as having been seriously injured, and 15 others were slightly injured. This accident was caused by the draw-bar having been pulled out of the tail end of one wagon, and remained attached to the front end of the wagon that was following ; one end dropped on to the sleepers and ballast, and the draw-bar acted as a lever to lift the wagon off the rails. In this case seven wagons and six carriages were all thrown off the rails, and, with one exception, fell over the bank, which was there about 39 feet in height, and came to rest at the bottom of it greatly damaged. There is no difficulty whatever in stating how this class of accident may in future be prevented, although it will probably necessitate an alteration in the greater portion of railway rolling stock. It consists in using for the future no draw-bars of sufficient length under the vehicles, so that in the event of their fracture, or their being drawn out of the frame of a carriage or truck, by the absence of a cotter or screw nut, and their remaining hanging to the draw-hook of the draw-bar of the following vehicle, they shall not be long enough to reach the ballast, sleepers, or rails, or to serve as a lever for lifting the leading end of the truck off the rails. The continuity of the strain through the truck, which at present is conveyed by means of these long draw-bars, can be maintained, if thought necessary, by means of two tie rods near the centre, passing through and ending at the outer side of the headstocks of the truck ; or the framing of the trucks may be strengthened, and the necessity for these through draw-bars be done away with. But the fact is that the danger may be provided against in a variety of ways. The question, however, is a very serious one, deserving the careful consideration of all railway companies, as a similar accident to that which happened to the empty down coal train from Poplar to Brent sidings on the night of the 28th ultimo might occur at any moment, in front of the fastest trains that run on any of the lines in England, where no warning whatever can be given, and where the best fitted passenger trains, with all the most recent improvements, might be suddenly wrecked, possibly with the most disastrous results, without a single servant of the company owning the trains being to blame for its occurrence. I hope I have said sufficient to attract the attention of the Directors of all Railway Companies in the United Kingdom to this subject.

Major-General Hutchinson has also reported the result of his inquiry into the circumstances connected with the fatal accident caused by the explosion of the fire-box of the engine of a goods train, near South Stockton station on the Darlington section of the North Eastern Railway, on the 26th of December last. From a careful inspection of the exploded fire-box, and from a consideration of the evidence, I have formed the conclusion that the explosion of the copper fire-box of engine No. 204 was probably occasioned by the crown of the fire-box having become overheated from want of water, and when thus weakened, having been unable to resist the pressure caused by the sudden creation of steam upon water being admitted into the boiler just as the engine was drawing up behind a mineral train at Thornaby Junction. The reasons which have led me to this conclusion are—1. The appearance of scorching on the copper plate on the inside of the fire-box near the place of fracture, which was at the top of the fire-box, over the fire-hole door, where the flames are projected (owing to the brick arch) before entering the tubes ; this same appearance being also visible on the adjacent bolt heads and nuts of the roof stays. 2. The fact of the driver having been seen to use the regulator just before the explosion. 3. The fact that the engine had been only about 21 months in use, and that the copper fire-box and stays were generally in good condition, the construction of the fire-box being of the usual type. Whether the want of water was attributable to carelessness on the part of the deceased driver, or to some defect in the water gauge having misled him as to the height of the water, it is impossible now to say. According to the evidence the gauge appears to have been properly examined on the 22nd December, and to have been observed to be in working order on the morning of the explosion. It is certainly most desirable that duplicate water gauges should be fixed to all boilers. The difference of level between the top of the boiler and the crown of the copper fire-box, amounting only to about 13 inches, was certainly small in the case of this engine, and would of course quickly allow the crown of the fire-box to become uncovered without very constant attention. I am not aware of the greatest difference of level which exists, but I know that some locomotive engineers keep down the crown of the fire-box 20 inches

below the top of the boiler, and that 15 to 18 inches is a common difference of level. So small a difference as 13 inches should as far as possible be avoided. The failure of the lead plug (which had been removed from the fire-box by order of the Locomotive Superintendent soon after the explosion) to melt when the crown of the fire-box became heated appears to have been owing to the bottom surface of the lead having become covered with a hard incrustation. Some locomotive engineers think these plugs perfectly untrustworthy; others on the contrary use them, but have them very frequently renewed. The plug in the present instance had not been renewed for four or five months, the boiler smith stating that there was no regular time for renewal. There can be no grave objection to the use of these plugs, and if their renewal is made peremptory at short intervals when an engine is in the sheds for overhauling, there would be comparatively little fear of their not being in a state of efficiency in case of need.

Colonel Yolland has also reported the result of his inquiry into the circumstances which attended the collision that occurred during a dense fog, on the 4th February last, between a passenger train and a light (goods) engine, about 150 yards from the Bricklayers' Arms junction signal-box, on the branch to the Bricklayers' Arms yard of the London, Brighton, and South Coast Railway, somewhere about 4.55 p.m. From the statements it appears that on the afternoon of the 4th February the fog was so dense in the vicinity of New Cross and the Bricklayers' Arms junction, that the drivers on the engines could not see the signals, and the fogmen on the ground could not see the signal lights, and they had to watch the working of the signal wires before they could decide whether the signals were on or off, and determine upon the necessity of putting fog-signals on the rails, or of telling the engine-drivers when the signals were on or off. The Company's fog-signalling regulation, contained in the Appendix to the Service Time Table Book, which applied to the fog-signalling performed on this occasion, and which had reference to this collision, is as follows :—" 1. The fog-signals must be placed on the rail (label upwards) by bending the leaden clips round the upper flange of the rails. When the engine passes over one or more of these fog-signals they will each explode with a loud report, and on one or more of these fog-signals exploding, the engine-driver must instantly shut off steam, whistle for the guard's brakes, and bring his engine and train to a stand, and, if at a distant-signal, proceed cautiously at a slow rate of speed as far as he can see the line is clear, or until he reaches the home-signal, at which he must again stop until he receives an 'All right' signal to proceed." As a consequence of the density of the fog, the trains were not enabled to run at the appointed times. About 4.44 a light (goods) engine, running with the tender in front, left New Cross station on the up main line for Willow Walk and the Bricklayers' Arms branch, and at 4.49 p.m, it was turned by means of a pair of facing-points on the up main line, worked from the Bricklayers' Arms junction signal-box, on to the branch leading into the Bricklayers' Arms yard, the signalman at the Bricklayers' Arms junction signal-box calling out to the engine-driver, " Right in," which the driver understood to mean that the line was clear to the North Kent junction; shortly after that the engine ran over and exploded a fog-signal, but the driver did not stop but kept moving on at the rate of about five miles an hour, until they neared the north end of the loop line, when he observed a white light on the near side about half the length of his engine from him, and he then turned on the steam the reverse way, but the engine was overtaken and run past by a passenger train engine, travelling on the up local line, and the tender of his engine was thrown off the rails, while the leading brake-van and three carriages in the passenger train were also thrown off the rails, but fortunately remained coupled together, as the train was running at the time on a high embankment close to the bridge that carries the branch line over the East London Railway. The train which had overtaken and run into the light engine was the 3 p.m. up passenger train from Epsom, which was running very late in consequence of the fog. It consisted of engine and ten vehicles, including brake-vans with two guards. It was fitted throughout with the Westinghouse brake. This train left New Cross on the up local line about 4.47 p.m., and the driver states that they passed over some fog-signals at the Bricklayers' Arms junction distant-signal, and he drew up cautiously to the stop-signals, when the man who was acting as fog-signalman told him that it was all right to proceed on the local line to London. It may here be mentioned that the fog-signalman made a mistake in saying that it was "All right" on the up local line for a train to proceed, as the facing-points on the up main line were then open for the light engine travelling on the up main line to pass from it on to the branch line leading into the Bricklayers' Arms yard, and in consequence of the interlocking of the points and signals it was impossible for the up local line signal to be off when the passenger train engine reached the Bricklayers' Arms up home or stop-signal. This mistake of the fog-signalman justified the engine-driver of the up passenger train running forward to the Bricklayers' Arms junction, and the driver says that he could not see the signals, but still proceeded cautiously, and shortly after passing the Bricklayers' Arms junction signal-box, he heard a fog-signal explode, but could not understand the meaning of it, and he did not stop his engine, and soon after he came into collision with the goods engine knocking the tender of that engine off the road, and breaking the steps off his own engine and causing the tank to leak. But this engine did not leave the rails. The sides of the carriages were damaged. The fog-signal on the Bricklayers' Arms

branch was exploded about 25 yards from the facing-points at the Bricklayers' Arms junction, and the collision took place about 116 yards beyond it, so that there was plenty of space for a train fitted with the Westinghouse brake to have been brought to a standstill before the collision took place. This collision was the direct result of the disobedience of the order, which I have quoted, on the part of the driver of the passenger train, that directs that when a fog-signal explodes the engine driver must "instantly shut off steam, whistle for the guard's brakes and bring his engine and train to a stand." It will also be noticed that the engine driver of the light engine also disobeyed the order respecting the fog-signals, and I may remark that safe-running during such dense fogs cannot be reckoned on unless engine-drivers are made to observe the Company's rules and regulations with respect to fog-signals. To prevent similar mistakes in future on the part of the fog-signalman stationed at the up stop-signals, it would be desirable to attach a board to the wire which actuates the signal with the name of the line for which it is the signal printed on the board.

Colonel Yolland has also reported the result of his inquiry into the circumstances connected with a collision that occurred during a dense fog on the 4th February last, near the Bricklayers' Arms junction, between two down passenger trains belonging to the London, Brighton, and South Coast Railway Company. From the statements it appears that, in consequence of the dense fog that prevailed on this line in the vicinity of London on the day in question, the 4 p.m. down express train from London Bridge to Brighton did not leave London Bridge Station until 4.56 p.m.; that it was stopped at the Spa Road signals about eight or nine minutes, again at the Blue Anchor Signals about eight or 10 minutes, and when permitted to go on from thence, the train ran over fog-signals at the distant signals worked from the Bricklayers' Arms junction, and then proceeded very slowly and ran over some more fog-signals just before reaching the Bricklayers' Arms junction stop-signals, where the fog-signalman told the engine-driver to go on a few yards more, and he would find the stop-signals and another fog-signalman there. This train consisted of an engine and 10 carriages, including brake-vans, all fitted with the Westinghouse brake, stated to be in good order. It is said to have stood at these stop-signals about 12 or 15 minutes, when the driver felt that something had struck his train in the rear, and it was forced forwards, but not more than three yards. This was brought about in the following manner:—The signalman in the Bricklayers' Arms junction signal-box stated that an empty train had been standing on the Bermondsey spur down line from 2.55 p.m., and that at 4.45 p.m., as he had had nothing given out as coming on the down main line, he signalled this empty train on to New Cross, and the line was cleared from New Cross for it to proceed at 4.48 p.m.; but in consequence of the up traffic and the collision which had occurred on the Bricklayers' Arms branch about 4.47 p.m., which is detailed in my report of the 27th instant, he was not sure that that collision had not blocked the Bermondsey down road, and he did not get the empty train away until 5.34 p.m.; and when that train passed his box, he said to the train signal clerk "Clear down," but instead of his clearing the line to South Bermondsey he cleared the Blue Anchor instrument on the main line. As soon as he found that the train signal-clerk had "cleared" the wrong instrument, he sent his assistant signalman with fog-signals to try and stop the train from the Blue Anchor, as he knew that he already had a train (the 4 p.m. down Brighton express) standing at his own stop-signals on the main down line, which express train had been given on for the down local line, but which turned out, however, to be the 4 p.m. down Brighton express train, intended to travel on the down main line and not on the down local line to New Cross from the Bricklayers' Arms junction; that his assistant signalman told him when he came back, that before he could get up past the first train, the second train had arrived. A mistake had also been made either in the signalling of the Brighton down express train from the A.B. signal-box or in the receipt of that signal. I think it was probably a mistake on the part of the train signal-clerk (a boy 16 years of age), who was possibly unnerved by the collision which had a short time before taken place on the Bricklayers' Arms branch, between a light (goods) engine and a passenger train. The train which ran into the 4 p.m. down Brighton express train, which was standing between the down distant and down stop-signals worked from the Bricklayers' Arms junction, with the last vehicle 150 yards north of the down stop-signal, was the 4.5 p.m. down train to Hastings and Eastbourne, which consisted of an engine and nine vehicles for Hastings and Eastbourne and four for Tunbridge Wells, fitted with the Westinghouse brake. According to the engine-driver, this train left London Bridge at 5.1 p.m.; it was stopped at No. 4 signals about five or six minutes, when they received an "All right" signal and they proceeded on to the Spa Road, and ran over fog-signals at the "distant" and "stop" signals, and they stopped at Spa Road stop-signals about five or six minutes and then proceeded on to the Blue Anchor, where they ran over two fog-signals at the distant and two at the home signal. This train remained 10 minutes at the Blue Anchor home, and then, in consequence of the mistake which the train signal-clerk in the Bricklayers' Arms junction signal-box had made in telegraphing "Line Clear" to Blue Anchor instead of "Line Clear" to South Bermondsey, they received a signal from the fog-man to start. The driver says that they went on very slowly till they got to the Bricklayers' Arms distant-signals and ran over two fog-signals there; that he had shut off the steam before reaching these signals and proceeded at a slow walking pace, and was looking out for the stop-signals at the Bricklayers' Arms junction, but before reaching them, he just got a glimpse of the tail lights of the 4 p.m. down Brighton train and struck the train immediately after, the steam being off at the time; that he put the Westinghouse brake on to his train at the same time, which stopped his train dead. The two trains were then coupled on together and ran on to New Cross, and then the 4 p.m. train was sent on to Brighton, and the 4.5 p.m. train to Hastings as soon as the signal was given to start. The collision is said to have taken place between 5.35 p.m. and 5.40 p.m. It appears to have been a slight one, and was caused by the mistake in signalling of the trains on the part of the train signal-clerk, combined with the fact that the Company's regulations for the guidance of engine-drivers do not appear to have been observed in this instance by the engine-driver of the Hastings train.

NOTES.

Electric Block System at Hackney Downs.—We notice that a correspondent to a contemporary lately stated that there was considerable delay at Hackney Downs junction on the Great Eastern Railway in consequence of that Company having adopted Sykes' Block System on that portion of the line. This was denied by Mr. Zohrab, the engineer to the system, on the ground that the work was not finished, and therefore Sykes' block could not possibly be used, and would not be ready to come into operation for some few days; the junction was still worked upon the old block system, and that if there was any delay it was due to that mode of working and not to Sykes'. An assertion like that of the correspondent only illustrates how careful we should be in publishing anything for fact, unless we are perfectly sure that our information is *bona fide*. We learn on good authority that the Great Eastern Railway are fitting from Hackney Downs junction to Clapton Station with the Sykes' system, and that it will be brought into use very shortly. Seeing how well the system is working on other lines we think the Great Eastern Railway Company will find it a very great safeguard in working the thick and fast traffic at Hackney Downs. We shall hope to give a full description of the working of the junction by the Sykes system in a future number.

Railways in Roumania.—A Government Bill has been submitted to the Roumanian Chamber of Deputies for the establishment of nearly 230 miles of local railways, to unite a number of the principal towns with the existing railways, and also with the Danube. Its cost is estimated at about £3,700 per mile, and will be met by the districts interested in the construction of the different lines, the Government granting them an annual subsidy of £14,500. The gauge will be the same as that of the existing lines, 4 ft. 10 in., but will be constructed on a more economical plan. It is expected that the new line will be open in 1884. The contracts for wagons given out by the Belgian State Railways have created a certain amount of activity, especially in the steel works and steel mills. The demand for tyres will probably enable manufacturers to get rid of stocks of ingots which have been accumulating for some little time. With this exception, the market remains quiet. It is stated that in several of the factories at Schafthausen, dynamo-electric machines will be set up for the transmission of power by electricity. Two machines have already been erected, and are working satisfactorily. They are driven by a water-wheel, and the electricity is conveyed to several works by means of large copper wires. The issue of April 30 contains particulars of the tenders for coal wagons, lately received by the Administration of the State Railways. The quantity purchased consisted of 1,500 side-door 10-ton coal wagons, with Stilmant brakes; and 500 similar ones with screw brakes, all in lots of 50. The offers were as follows: Wagons with Stilmant Brakes.—La Métallurgie, Brussels, 18 lots at prices varying from 102,450 fr. to 109,900 fr. per lot. A. and V. Halot, 6 lots at prices varying from 102,450 fr. to 112,500 fr. per lot. La Sociétié de Morlanwelz, 6 lots, commencing at 105,250 frs. Les Usines et Fonderies de Baume, several lots, 105,950 fr. Other firms quoted higher prices than the above for various lots. The average of the lowest 30 tenders was about 108,000 fr. Wagons with Screw Brake.—Nicaise del Cuve, 10 lots at prices varying from 121,200 fr. to 131,200 fr. per lot; La Société Dyle-Bacalan, 2 lots at 124,000 fr.; 2 lots at 125,000 fr., and others ranging up to 131,000 fr. La Métallurgie, 3 lots at 124,900 fr., and 1 lot at 125,700 fr. Other tenders were received, ranging up 146,700 fr. per lot, the average of the lowest 10 being about 125,800 fr. per lot. It will be seen that La Métallurgie has secured the larger part, the remainder being distributed among other firms according to price.

Use of Petroleum as Fuel.—Although many attempts have been made to utilize a substance which is apparently so valuable a means of heat-production, the writer is of opinion that none of the schemes for making iron or running locomotives with this fuel have ever proved financially successful. The cause of this is simply the fact that there is more heat-producing power in a dollar's worth of coal than in a dollar's worth of petroleum. This amount is taken as being 444 lb. anthracite, giving 6,005,544 heat units—421 lb. bituminous coal giving 6,510,765 heat units—or 103 lb. petroleum giving 2,182,766 heat units. Practically, however, from 15 per cent. to 25 per cent. of the heating power of the coal is not utilized. Therefore, if it were possible to consume petroleum thoroughly, so as to develop the whole of its theoretical heat-producing power, this difference would be considerably diminished. It is not considered probable that the cost of petroleum will be so reduced, and that of coal so increased, as to bring the two substances on to the same footing; but even if that were to be the case, the enormously increased demand for petroleum resulting from its use as fuel would inevitably tend to re-establish the difference in favour of coal. The advantages of petroleum—freedom from smoke and cinders, and the much smaller space required for its storage—are not likely to counterbalance the great cost.—New York.—*The Railway Gazette.*

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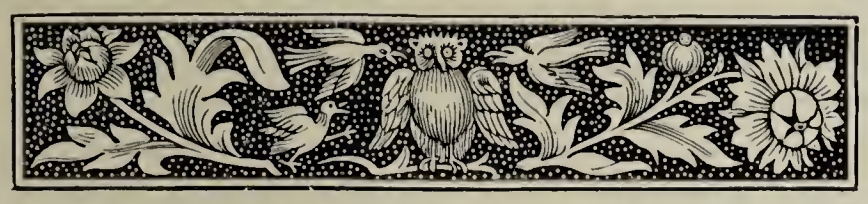


LONG SPAN BRIDGES AND VIADUCTS, IN IRON, STONE, BRICK, AND TIMBER.

THE expression, "long span bridge," having a mere arbitrary meaning, we premise our observations by defining the limit of short span bridges as one hundred feet clear span.

In the earlier days of construction, bridges of long span were most usually built upon the suspension principle, being carried by chains; we specially refer to the chain form of bridge, as there is some confusion in the use of the term "suspension bridge," thus, for instance, in Leeds there are some so-called suspension bridges over the River Aire, which are really carried by rigid arches, springing below the roadway or flooring, but at the centre rising above that level, so that the *centre part* of the floor is sustained by suspension rods fixed to the arch on each side of the structure. This system, however, is not appropriate for long span bridges on account of the difficulty of arranging suitable transverse bracings to resist lateral oscillation.

One of the most notable railway suspension bridges is that over the Niagara, in America, carried by wire ropes, and designed by Mr. Roebling; in this instance, the bridge is laterally steadied by guy ropes.

The prime objection to suspension bridges for railway purposes has always been their lack of stability, although this has, to a certain extent, been remedied by hanging the chains or ropes in an inclined, instead of a vertical plane, the suspension rods, of course, following the same inclination.

There can be little doubt that so far as railway bridges in iron are concerned, some form of rigid girder construction will give the most satisfaction, both in stability and economy in cost, and, moreover, particular facilities are afforded for erecting this class of work without involving the necessity of using expensive scaffolding, a matter of great consideration in very lofty works.

We may divide the structures of which we are treating into two classes, viz., bridges of one, two, or three spans, of which the dimensions are fixed by the local circumstances, and long viaducts, of which the spans may be made of any length that appears most suitable in the judgment of the engineer.

In the first place, we will inquire into the criteria by means of which the most economical relation of span to height may be determined. This we may most conveniently explain by an example, assuming that the girders are discontinuous (the question of continuous girders we shall consider subsequently).

We observe from the well-known formula, $S = \frac{w\,l^2}{8\,d}$, in which S = total strain on centre of one flange, w = load per lineal foot, both in tons, l = span in feet, and d, depth in feet, that the sectional area (varying as the strain) will vary directly as the load and square of span and inversely as the depth, so the total weight of girder varies in the same ratio except the square is replaced by the cube of the span.

There has been a rough rule long used by some contractors which takes the weight of (main) railway girders per foot in cwts. as one-tenth of the span in feet for each road, thus for a bridge carrying a single line of railway, if 120 ft. span, the two main girders would come out at 12 cwt. per foot, assuming the girder to be economically proportioned, and in light viaducts, we, of course, can proportion the depth to span to suit our own views, but to take a fixed factor, such as this, *in all cases*, is rather too rough a course if we require fairly approximate results, for not only do the loads vary in different localities, but are progressively increasing on most of our railway systems. We must calculate for the maximum load, that is, a train of the heaviest locomotives used on the railway, this being the test adopted by the Board of Trade.

In Vol. I. October, November, and December numbers, we published an investigation of the general question of "Bridge Loads and their Distribution," and from that we have deduced a table giving a very close approximation to the weights of ordinary girders of practical design, based on strain allowances of 4 tons compression and 5 tons tension per sectional square inch for wrought iron. We here adopt this table for present use, those who desire to prepare others to suit different data or exceptional designs will find the analytical method fully set forth in the papers above referred to.

Let W = the weight of the girder or arch in tons per lineal foot.

W_2 = total load in tons upon girder or arch (*i.e.* exclusive of weight of girder).

c = constant taken from table. $W = W_2 \times c$.

The table gives constants both for *uniform section* of flanges and for *uniform strain* on flanges, in the latter case the plates diminish towards the points of support.

WROUGHT IRON GIRDERS.

Uniform Section of Flanges.	Uniform Strain of Flanges.	Span ÷ Depth.	Uniform Section of Flanges.	Uniform Strain on Flanges.	Span ÷ Depth.
·00182	·00145	8	·00259	·00200	13
·00198	·00156	9	·00274	·00211	14
·00213	·00167	10	·00289	·00222	15
·00228	·00178	11	·00304	·00233	16
·00243	·00189	12			

WROUGHT IRON ARCHES AND CHAINS.

Rigid Arch.	Chain.	Span ÷ Depth.	Rigid Arch.	Chain.	Span ÷ Depth.
·00085	·00073	4	·00125	·00104	9
·00093	·00079	5	·00133	·00110	10
·00100	·00085	6	·00141	·00116	11
·00108	·00091	7	·001495	·00121	12
·00117	·00097	8			

By some it is thought that lattice girders are lighter always than plate, but as we cannot keep our webs down to theory this does not always obtain; we gain, however, by making lattice girders of greater proportional depth than plate girders usually follow.

For our purpose the above table applies to both classes of girder. Let now, for our example, a viaduct be proposed, to have a length of 3,000 ft., and an average height from the ground surface of 200 ft., it is to carry a double line of railway on girders placed under the rails, one under each rail, the four being cross-braced together and having outside brackets to carry the overhanging width of floor, and the parapets or handrails. Let the width of flooring be 26 ft., being composed of $\frac{1}{4}$ in. buckled plates covered with six inches of ballast.

The girders to be carried on piers formed of columns grouped ten columns to each pier, and built up in ten foot lengths properly braced diagonally and horizontally. Each column will be assumed as 18 in. in diameter and $1\frac{1}{4}$ in. thickness of metal.

The bracing bars to be tee iron 6 in. by 3 in. by $\frac{1}{2}$ in. thick, and all the columns to rake 1 ft. in 50 ft. of height, hence, as the average height is 200 ft., the average width and breadth will exceed by 2 ft. the top width. Let the top width be 6 ft. The breadth will be the sum of the distances between the outside rails (5 ft. + 6 ft. + 5 ft.) 16 ft., and from the outside rails to the end columns, and if these be placed so that each end of the pier in plan is an equilateral triangle (on the 6 ft. base), we get the additional distance (between centres) by multiplying one side by sine 60 degrees—thus, $6 \times 0.866 = 5.196$ ft. so that the total top breadth is $16 + 2 \times 5.196 = 26.392$ ft.; or 26 ft. 5 in. nearly.

The average width and breadth then, between centres will be 8 ft. and 28 ft. 5 in. respectively. The sizes assumed for the columns must be afterward examined to see that we have ample strength.

We must now determine the weight and thence the cost of piers, let them be carried on cast-iron piles ten feet below ground surface.

Taking a ten foot height or tier, and allowing one foot at each end of each column for flanges, lugs, brackets, &c., we find in the eight columns, 18 in diameter, a surface of $(10 + 2) \times 10 = 120$ ft. length by 4.712 (ft. circumference), which equals 565 sq. ft., which at $1\frac{1}{4}$ in. thick weighs 47.5 lbs. per sq. ft., making 26,837 lbs. = 12 tons (nearly). Then for one average pier 200 ft. high plus 10 ft. for foundations, the cast-iron will be 21 tiers × 12 tons × (say) £9 per ton = £2,268 per pier.

We must now take the wrought-iron bracing. For one tier it will pass round from column to column horizontally, and there will be vertal cross-bracing between the columns; for the lengths of the horizontal bracing we have to take the distances from centre to centre of the columns less their diameters. For the four bars between the columns under the lines (5—1.5) 3.5 ft. each; for the two under the "six-foot" between the lines (6—1.5) 4.5 ft. each; for the four running longitudinal through the thickness of the pier (8—1.5) 6.5 ft. each, and this will also be the length of each of the end bars running to the extreme side piles.

Each vertical bracing will consist of two diagonal bars of which each forms the hypothenuse of a right-angled triangle having the height of a column 10. ft for its height (this allows a little to make up for bolts, as the centres of the lugs will be below the tops and above the bottoms of the columns), and one of the horizontal bars for its base, from the ordinary properties of the right-angled triangle we get the lengths of the bars, thus: for one end bay $\sqrt{10^2 + 6.5^2} = 11.9$ say, 12 ft.; for one under the 5 ft., $\sqrt{10^2 + 3.5^2} = 10.6$ ft.; for one under the "six-ft.," $\sqrt{10^2 + 4.5^2} = 10.9$, say 11 ft.; and for one through the thickness of the pier, $\sqrt{10^2 + 6.5^2} = 11.9$, say 12 ft. The total will therefore be

8 bars in end bays	12	× 8 =	96.0	ft.
8 ,, under 5 foot	10.6	× 8 =	84.8	,,
4 ,, ,, 6 ,,	11	× 8 =	88.0	,,
8 ,, through pier	12	× 8 =	96.0	,,
			364.8	feet of 6″ × 3″ × $\frac{1}{2}$″ tee iron.

This size of tee iron weighs 15 lbs. per foot, and there will be 20 tiers for each average pier; the piles are not cross braced, hence the total for one such pier will be—364.8 feet × 20 tiers × 15 lbs. = 109,440 lbs. = 49 tons

nearly. Assuming 16 lbs. per ton for this work. we have 49 tons × £16 = £784, bring the total cost of one average pier up to £2,268 + £784 = £3,052.

It may be observed that these prices are taken for each case that arises, as, of course, they vary constantly, and no rule can be laid down for them.

We must now see to the cost of the superstructure so far as it can be varied, that is, the cost of the girders, for the floor and cross-bracing will be the same, however the length is divided up.

Let us try a lattice or triangular girder, and take its depth to be one-eighth of the span—the flanges, &c., being adapted to *uniform strain*—the table gives as the constant for girder weight 0·00145. We must ascertain the load on the viaduct per lineal foot *without the girders.*

Cross-bracing, say 150 lbs. per foot; floor plates ($\frac{1}{4}$-inch buckled plates weigh 12 lbs. per superficial foot, including rivets) 26 ft. width × 12 lbs. = 312 lbs. per foot. Ballast on floor plates 6 in. (at 60 lbs. per foot super) = 26 feet × 60 lbs. = 1,560 lbs. per foot, permanent way and handrails 150 lbs. per foot.

Next there is the moving load to be determined. For a long span the strains produced will be equal to a uniformly distributed load equal to the weight of a train of locomotives of the heaviest type, this may be taken at 1.45 tons per foot per line of rails, or 2.9 tons per foot of bridge; the total load per foot run exclusive of girders, will, therefore, be:—

Cross-bracing ...	150 lbs. per foot run.			
Floor plates	312	,,	,,	,,
Ballast	1,560	,,	,,	,,
Permanent way, &c.	150	,,	,,	,,
	2,172	,,	= 0.97	tons per foot run.
Moving load			= 2.90	,, ,, ,,
				,, ,, ,,
			3.87	,, ,, ,, exclusive of girders

This multiplied by l, the span will give the quantity, W_2; so W being the weight of the girders in tons per lineal foot;

$$W = W^2 \times c = 3.87.\, l \times 0.00145 = 0.0056.\, l.$$

The total weight of the superstructure will be, 3,000 feet long × 0.0056. l per foot = 16.8. l tons. Taking the construction and erection of the girders at £20 per ton, the total cost of the superstructure will be estimated at 16.8. l × £20 = £336. l.

Leaving out the end abutments, which will be of brick or masonry, to form an abutment for the bank; if N = number of piers, then will the total cost be:

$$C = N \times £3{,}052 + l \times £336.$$

The number of piers will be one less than the number of spans, hence:

$$N = \frac{3{,}000}{l} - 1\,;\ \&\, C = \left(\frac{3{,}000}{l} - 1\right) \times 3{,}052 + l \times 336$$

We have now to determine a *minimum value* for this equation by means of the differential calculus as applied to the doctrine of "Maxima and Minima."

Make the first differential co-efficient = o, thus:

$$\frac{d\,C}{d\,l} = -\frac{3{,}000}{l^2} \times 3{,}052 + 336 = o : 336.l^2 = 9{,}156{,}000$$

$$l = \sqrt{\frac{9{,}156{,}000}{336}} = 165 \text{ ft.}$$

To ascertain whether the result answers to a maximum or minimum, we must find the sign of the second differential co-efficient:

$$\frac{d^2\,C}{d\ l^2} = \frac{3000}{l^3} \times 3052 = \frac{3000}{(165)^3} \times 3052 = 2.04$$

it has, therefore, a + sign, in which case the value l = 165 feet gives a minimum value to the equation to C.

This, however, the theoretical span for the average height of pier taken will not exactly divide into the total length, making a little more than eighteen spans, adopting that number each span measured from centre to centre of pier would be 166 ft. 8 in.

If the piers do not vary much in height it will be proper to use a uniform span throughout; but should the variation be great, the spans may also be varied with advantage.

Suppose, for instance, our example is across a valley, giving, say for 1000 ft. in the centre a pier height of 250 ft., then the cost of each pier would be on the above data very nearly £4,580, proceeding in a similar manner to that pursued above:

$$N = \frac{1{,}000}{l} - 1\,;\ \&\ C = \left(\frac{1{,}000}{l} - 1\right) \times 4{,}580 + l \times 112$$

$$\frac{d\,C}{d\,l} = -\frac{1{,}000}{l^2} \times 4{,}580 + 112 = 0\,;\ 112\ l^2 = 4{,}580{,}000$$

$$l = \sqrt{\frac{4{,}580{,}000}{112}} = 202.2 \text{ ft.}$$

The nearest practical division of the 1,000 ft. giving 200 ft. span.

Let us now examine if we have allowed sufficient metal for direct strength in the columns.

On account of the manner of their bracing each will act with a virtual or effective length of ten feet; we take the lowest tier of columns as carrying the weight of the pier as well as that of the superstructure. We must, however, take only the eight columns directly under the girder, they will in the last case carry 200 ft. of superstructure and their own weight, four-fifths of the pier which will be for 250 ft. high.

The cast iron in one tier is 12 tons, bracing 2.5 tons making 14.5 tons per tier, and for the weight on the bottom columns, $\frac{4}{5}$ (25 tiers × 14.5 tons) = 290 tons. Now, for the superstructure we have the above formula for the girders, viz., 0.0056. l tons per lineal foot, or for the whole span 0.0056 l^2 = 0.0056 × $\overline{200^2}$ = 224 tons. The remaining weight of superstructure is 3.87 tons per lineal foot × 200 feet = 774 tons, so the total load upon each column would be:

$$\tfrac{1}{8}\ (290 + 224 + 774) = \frac{1288}{8} = 161 \text{ tons.}$$

The breaking weight of the columns may be found from Professor Gordon's rule deduced from Professor Hodkinson's experiments.

If W = breaking weight in tons; r = ratio of length to diameter; a = sectional area of metal in square inches; then

$$W = \frac{36 \times a}{1 + \frac{r^2}{400}} = \frac{36 \times .785\,(18^2 - 15.5^2)}{1 + \frac{\left(\frac{10}{1.5}\right)^2}{400}} = \frac{36 \times 65.77}{1 + \frac{(6.67)^2}{400}} =$$

1,230 tons.

This divided by the actual load, 161 tons, gives as a factor of safety 7.64, so there is quite sufficient strength; and, in fact, the upper columns may be reduced, if care is taken during erection *to be sure the thin columns are put in their proper positions*. On the top columns the load is about one-fifth less than on the bottom ones; in regard to the latter, however, especial strength is requisite, as, from their positions, they are liable to passing blows. The question of stability to resist wind pressure must now be considered. We shall take 50 lbs. per superficial foot as the maximum wind pressure. The wind blowing through the face girder will strike, but with much reduced force those behind, as, taking the most disadvantageous direction of wind—viz., at right angles to the girders, the front one should theoretically form a shield to those behind; we shall, however, take twice the estimated surface of the one lattice girder, which would be about one-quarter of a plate girder of similar dimensions, of which, therefore, we take half the surface, or $\frac{200 \times 25}{2} = 2500$ sq. ft. The 25 ft. depth being one-eighth of the span 200 ft. The great height, 250 ft., assumed will give the wind an enormous leverage for its moment at the base of the pier, being for the pressure on the superstructure $250 - \frac{25}{2} = 237.5$ ft.

A round column offers to wind pressure one-half the resistance of a flat surface of the same height, and of a width equal to the diameter of the column, and if we take the resistance of half the columns to 50 lbs. per square foot we are probably over the mark, for the front columns must to some extent shield those behind, more especially as they throw the wind off laterally, somewhat after the fashion of a cut-water. The top tiers of columns are modified for the reception of the main girders, which may be carried by the top flanges as in several of the large Warren Girder Viaducts, then for the depth of girder the wind pressure need not be taken on the columns, having been already taken for that area in the superstructure. In this mode of construction also there can be no danger of the wind *overturning the girders on their bed-plates*.

The area (effective) to be taken for one pier will be $225 \times 5 \times \frac{1.5}{2} = 843.7$ sq. ft., and its mean leverage height from the ground 112.5 ft.

We shall have then for the whole overturning moment at the ground level:

		ft. lbs.
Overturning moment of wind on superstructure	$2500 \times 237.5 \times 50 =$	29,687,500
Do. do. do. pier	$843.7 \times 112.5 \times 50 =$	4,745,812
		34,433,312

Which is equal to 15,372 ft. tons.

The estimated weight of the pier and 200 ft. of superstructure is seen from our previous calculations to be 780.5 tons, the running load is omitted in considering the stability at present as the structure must be sufficiently stable both loaded and unloaded. If we give the piers a lateral rake on each side of one foot in 25, the width at the base will be 46.39 ft., corresponding to a leverage of 23 ft., from the centre of gravity horizontally to the edge of the pier, so the moment of resistance will, $780.5 \times 23 = 17{,}951$ ft. tons. This does not give a sufficient margin of safety, hence the end piles must rake more or the piers must be weighted. Let us see what filling the columns up with concrete will do.

The inside area of each column will be 1.31 sq. ft., hence the contents of ten columns 125 ft. high (we omit the modified ones carrying the main girders) will be $125 \times 1.31 \times 10 = 1637.5$ cubic ft., and assuming the concrete to weigh 120 lbs. per cubic foot, the additional moment of resistance will be $\frac{120 \times 1637.5 \times 23}{2240} = 2018$ ft. tons bringing the total up to 19,969 ft. tons, or nearly one-third more than the moment of overturning force. This, however, is not sufficient, as we should have twice the overturning force represented in the stability. This, then, must be obtained by further raking the piles. We require a resistance of 30,700 ft. tons in round numbers. We have, with the concrete, 868 tons dead weight, the half-width of base of pier must therefore be $\frac{30{,}700}{868} = 35.4$ ft., giving a total base width of say 71 ft.

The stability under the moving load must now be examined. We will take the test load of a string of engines and tenders, deducting spaces between engines and tenders, the surface for the wind to act upon will be 180 ft. × 6 ft. = 1,080 sq. ft., giving $\frac{1{,}080 \times 50 \times 255}{2{,}240} = 6{,}147$ ft. tons. The centre of gravity of this load will act (if the wind blows on the most unfavourable side), $35.5 - 5.5 = 30$ ft. from the edge of the pier, and the load is 290 tons, giving a moment of resistance 8,700 ft. tons; but as the train would not be *resting* on the viaduct in a hurricane, even if the authorities were careless or foolish enough to let it pass on to it the absolute safety of the whole work would not be imperilled, for the total factor of safety would then be *momentarily* reduced to 1.83 from 2.

Of course the piers must be rigidly braced in order that they may act as if constructed in one piece each.

If it is found impracticable to make the piers of sufficient width to give the required stability, masonry piers may be used, being made more or less hollow according to the weight required in them.

We will next pass to the use of continuous girders. According to the ordinary mathematical theories of these girders, as expounded by Clapeyron, Humber, and others, a girder of an indefinite number of spans will at its centre have a span closely approximating in its circumstances that of a girder rigidly fixed at both ends, that is, when the viaduct carries a uniformly-distributed load throughout, such as its own weight only. Then if w = load in tons per lineal ft.; l = span in ft.; d = depth in ft.; S = strain on either flange at centre of span; S_1 = strain on either flange over pier—then

$$S = \frac{w.l^2}{24.\ d}, \& \ S_1 = \frac{w\ l^2}{12.\ d}$$

From these quantities the strains will vary until at the end span, we have conditions closely approximating that of a girder fixed at *one end*, and freely supported at the other; where $S_1 = \frac{w\ l^2}{8\ d.}$ at the fixed end and o at the other. Another maximum strain occurs at a point $\frac{3}{8}$ of the span from the freely supported end, which we find to be $S = \frac{w\ l^2.}{14.2d.}$

Those who desire to examine the elaborate investigations from which these formulæ are deduced, are referred to the writings of the above and other authors on the subject, as, had we the space, it would be out of place to interpolate them in an original article.

The variations of loads on a continuous girder are necessarily very numerous, but we have only to consider the positions which give to each part its maximum strain.

In order to keep the strains over the piers alike throughout under a uniform span, the end openings should be four-fifths of the span of one of the intermediate openings all of which are to be equal.

All fixed or continuous girders have certain points where a change in kind of strain occurs: at the part of the span which lies in the *centre* the girder deflects showing a *concave* upper surface, but at and near the *fixed end* or *ends* the upper surface is *convex*, and where the curves meet is called the point of contrary flexure.

The result is that, the span, if we are dealing with a girder fixed at both ends, virtually consists of a centre girder supported at its ends by two cantilevers, the points of support corresponding with those of contrary flexure. In the girder fixed at one end, there is one cantilever, supporting one end of a girder of which the other is freely supported on a pier or abutment, as the case may be.

First take the case of the girder fixed at both ends. We commence with a strain which, is the reverse of what would accrue were the girder merely supported, hence the strain at any point will be found by deducting the former from the latter, which, if x = the distance in feet from the point of support is determined by the well-known formula $s = \frac{w\ x}{2\ d}\left\{l - x\right\}$ hence deducting therefrom the quantity $\frac{w\ l^2}{12.d} = S_1$; x will give the position of the point of contrary flexure when s is made $= o$, that being the point where the strain disappears.

$$s = \frac{w\ x}{2\ d}\left\{l - x\right\} - \frac{w\ l^2}{12.d} = o\ ;\ \therefore \frac{w\ x}{2\ d}\left\{l - x\right\} = \frac{w\ l^2}{12\ d}$$

$\therefore\ l\ x - x^2 = \frac{l^2}{6}$; an adfected quadratic equation which will yield two answers on solution in the usual manner.

$$x^2 - l\ x = -\frac{l^2}{6};\ x^2 - l\ x + \frac{l^2}{4} = \frac{l^2}{4} - \frac{l^2}{6} = \frac{l^2}{12};\ x - \frac{l}{2} = \pm$$

$$\sqrt{\frac{l^2}{12}} = \pm \frac{l}{3.464};\ x = \frac{l}{2} \pm 9\ 29\ \frac{l}{3.464} = 0.5\ l \pm \therefore$$

$x = 0.21\ l$ and $0.79\ l$. These relative proportions of the spans indicating the positions of the two points of contrary flexure, which may practically be called a fifth of the span from each point of support.

If, now, it be supposed that instead of the farthest cantilever being in, the girder terminates on a free support at what *would be* its second point of contrary flexure, the position of the first and the actual strain over the pier are not altered, but the span is reduced to $\frac{4}{5}\ l$, showing why the end span should be four-fifths of the intermediate spans, the equality of the strains over the pier between the two spans may be proved by working them out for a 100 ft. span fixed at both ends, and an 80 ft. span fixed at one and freely supported at the other end, taking w = 2 tons and d = 9 ft.

For the first: $S_1 = \frac{w\ l^2}{12.d} = \frac{2 \times 100^2}{12 \times 9} = 185.\dot{1}8\dot{5}$ tons.

For the second: $S_1 = \frac{w\ l^2}{8\ d} = \frac{2 \times 80^2}{8 \times 9} = 177.\dot{7}7\dot{7}$ tons.

The discrepancy is due to practically taking $0.2\ l$ instead of $0.21\ l$ above; but as we cannot practically *actually reduce the section to nil* at the points of contrary flexure, the $\frac{1}{5}$ factor is quite near enough for practice. The only way in which we can apply these figures in practice is to the girder as carrying only the dead load. Having done this, we can add to the strains thus obtained, those additional ones due to the most disadvantageous positions of the moving load.

Having finally ascertained by how much the girders can be reduced in weight per foot, we can then determine upon the use of longer spans in the viaduct.

We will assume a girder 160 ft. span and 16 ft. deep, and determine as nearly as practice will allow the nature and variations of these strains, calculating first for the dead weight only; from the formula $\frac{w\ x}{2\ d}\left\{l - x\right\} - \frac{w\ l^2}{12.d} - s.$

Let the dead load be 2 tons per foot.

x	$\frac{w\,x}{2\,d}\left\{l-x\right\}$	$-\frac{w\,l}{12.d}$		S in tons.
0	0.00	— 266.67	= ...	— 266.67
10	93.75	— 266.67	= ...	— 172.92
20	175.00	— 266.67	= ...	— 91.67
30	243.75	— 266.67	= ...	— 22.92
40	300.00	— 266.67	= ...	+ 33.33
50	343.75	— 266.67	= ...	+ 77.08
60	375.00	— 266.67	= ...	+ 108.33
70	393.00	— 266.67	= ...	+ 126.33
80	400.00	— 266.67	= ...	+ 133.33

The minus sign indicates tension on the top and compression on the bottom members, the plus sign indicates the reverse. The strain dies out at 33.6 ft. We have only taken up to the centre of the span, on each side of which point the girders will, of course, be symmetrically formed.

If *one* span be now *completely* loaded, the points of contrary flexure will be moved nearer the piers, and the maximum strain will be brought upon the centre part of the girder, the strains over the piers will not be augmented to the maximum capable of occurring there, the loaded span will deflect under the live load, and will to some extent raise those on each side, at the same time throwing *their* points of contrary flexure nearer the centres of their spans, and this disturbance will continue until equilibrium is again established over the piers. Let the live or moving load be 3 tons per lineal foot. Then the additional strain coming from the loaded side to over the pier must be equilibrated by taking up an extra length on the unloaded side, if the plates were equally strained from each side, the extra strain would be $\frac{w\,l^2}{12\,d} = 400$ tons; but the other side as it is, cannot equipoise this; so, as it were, begins to give way until a balance is arrived at.

Now, from the principle of the continuous girder being virtually a central girder carried between two cantilevers, the strain over the pier may be found thus: let L = distance of point of contraflecture from pier; then

$$s = \frac{w}{2\,d}\left\{l-2L\right\}L + \frac{wL^2}{2\,d}$$

the first part being half the load on the central girder acting at the end of the cantilever and the second, the distributed load on the cantilever acting with its mean leverage. The expression simplifies to

$$s = \frac{w}{2\,d}\left\{l\,L - L^2\right\}$$

which obtains so long as the girder is symmetrically loaded and has equal strains at each end; but this will not be the case with the spans on each side of the loaded one and, indeed, of those following, though the inequality will decrease as we recede from the loaded span.

To determine the case for a long number of spans is exceedingly tedious, and is hardly worth while in dealing with practical cases, and probably the safest practical method of treating the case is to calculate the additional load as for a detached girder, and see where the summation of strains will place the points of contrary flexure.

Proceeding then with this load as proposed, and summing the strains, we have, calling them in this case s_1 to distinguish them from the first set for the unloaded girder.

x	$\frac{w\,x}{2\,d}\left\{l-x\right\}$		s in tons		s_1 in tons.
0	0.00	—	266.67	= ...	— 266.67
10	140.62	—	172.92	= ...	— 32.32
20	262.50	—	91.67	= ...	+ 170.83
30	365.62	—	22.92	= ...	+ 342.70
40	450.00	+	33.33	= ...	+ 483.33
50	515.62	+	77.08	= ...	+ 592.70
60	562.50	+	108.33	= ...	+ 670.83
70	589.50	+	126.33	= ...	+ 715.83
80	600.00	÷	133.33	= ...	+ 733.33

Working out the exact position of the point of contrary flexure which we see by the above lies a little beyond ten feet from the pier, we find it 11.5 feet from the pier. Then working out the moment over the pier to that length we find

$$s = \frac{w}{2\,d}\left\{l\,L - L^2\right\} = \frac{5}{2 \times 16}\left\{160 \times 11.5\right\} - (11.5)^2 =$$

266.83 tons.

For designing the centre part of the girder, there must be no strains *less* than those last given taken, starting from the 11.5 ft. from the piers at each end of the span.

We must next determine the maximum strains on the cantilever part of the girder.

The greatest strain over the piers will be when the whole spans on both sides are fully loaded, when it will be

$$\frac{w\,l^2}{12\,d} = 5 \times \frac{160 \times 160}{12 \times 16} = 666.\dot{6}7 \text{ tons.}$$

The strains on this part must now be worked out to the point of contrary flexure, which in this case will again be 33.6 ft. from the piers. $w = 5$ tons.

x	$\frac{w\,x}{2\,d}\left\{l-x\right\}$		$-\frac{w\,l^2}{12\,d}$		S_2 in tons.
0	0	—	666.67	= ...	— 666.67
10	234.38	—	666.67	= ...	— 432.29
20	437.52	—	666.67	= ...	— 229.15
30	609.42	—	666.67	= ...	— 57.25
33.6	666.67	—	666.67	= ...	+ 0.00

These will be the figures to work to in designing the cantilever parts:—

It will be noticed that between the two varying points of contrary flexure the strains on the top and bottom flanges will change backwards and forwards between tension and compression, but by designing to maximum strains we shall be right for taking the nearest approach, viz: 170.83 tons compression and 229.15 tons tension under different load-

ing, and using 5 tons per square inch for tensile and 4 tons per sq. in. for compressive strain, we shall get from the maximum, $\frac{229.15}{5} = 45.83$ sq. ins. and this will cover that required in compression, viz: $\frac{170.83}{4} = 42.70$ sq. ins., even without considering that in compression the rivet holes need not be deducted as they must in tension.

We will now see what is theoretically saved in the flanges by using the continuous girder.

In this case the sum of the areas of both flanges is: discontinuous, 296 sq. ins.; continuous, 240 ins.; a difference of 56 sq. ins., which, on the 200 ft. length, will amount to $\frac{56 \times 10 \text{ lbs.} \times 200}{13 \times 2240} =$ nearly 17 tons; which, at £20, represents a saving of £340 on each 200 ft. span; the girders, if discontinuous, would at the same rate cost £4480 as estimated, so considering the ratios between the two estimated amounts there would be a saving of 7.59 per cent. on the girders.

(To be continued.)

PORTSKEWET ACCIDENT.

IN our present issue we publish a report by Colonel Rich, R.E., of an accident which occurred on the Great Western Railway at Portskewet Pier Station. It would appear from this report that the driver had applied the brake so lightly that the air instead of exerting any useful effect upon the pistons of the vacuum cylinders simply leaked passed the holes in the piston rods and destroyed the vacuum on the upper sides of the pistons, thereby entirely nullifying the effect of the brake. That such a state of things could be possible seems hardly credible, but if the accuracy of Colonel Rich's report be accepted no other solution can be admissable. The object of these holes in the piston rods, we are told, is to allow the brakes to "leak off" for "shunting purposes," but as the brake, according to Colonel Rich's report, takes, in some cases, two minutes to "leak off," shunting is liable to become unduly and inconveniently delayed, according as the leakage-hole may be more or less stopped up with dirt.

The Midland and Great Western Railway Companies may have good reason to uphold this system of "leaking off," but the only advantage seems to be to enable carriages to be shunted with facility, although this can apparently be accomplished without the dangerous results of the "leak off" arrangement. The Automatic Vacuum Brake, supplied by the Vacuum Brake Company, will remain on for several hours, may be released by a porter from any individual carriage to which it may be supplied in a few seconds, or may be released from the whole train by the engine driver before leaving it.

There seems to be another advantage with the latter system over the "leak-off" arrangement. Whereas the vacuum in Midland and Great Western systems is destroyed top and bottom of the cylinders every time a stop is made, with the Vacuum Brake Company's system the vacuum in the reservoir and top side of cylinder remains always intact from one day's end to the other, so that, regarding capacity of reservoir space on each carriage as four times the cubical contents of the cylinder proper, we have, in a train of twelve coaches, to exhaust forty-eight times the quantity of air in the case of the Midland and Great Western Systems as in the Vacuum Brake Company's system. It may possibly be argued that with the Midland and Great Western systems the brakes are more rapidly released by the driver, as from the nature of their construction the vacuum is recreated a trifle more rapidly on the lower side of the piston, which has a tendency to induce a quicker release; but when this has to be accomplished at the expense of a "leak off" arrangement, the slight advantage in its favour is partially annulled. Again, the Duplex arrangement adopted on the Great Western Railway for obtaining and maintaining the vacuum is objectionable. The driver has an ejector, and also a pump, worked from a reciprocating part of the engine itself. The ejector is to create the vacuum promptly, and the pump to maintain it when running. With such a combination it is absolutely necessary that holes should be made either in the pistons or rods otherwise when the driver shuts off his ejector, which had created say 20 inches, and the speed of the engine was not sufficient for the pump to maintain it, the brakes would be applied. The arrangement adopted by the Vacuum Brake Company appears here to be highly ingenious. When air is admitted to the train pipe it flows freely to the bottom sides of the pistons, but is shut off from the top side and reservoir through the action of a small ball valve, which is immediately pressed on to its seat. The ball is very nearly in a state of equilibrium, the tendency being in a small degree to keep off its seat, so that, in the event of the vacuum being very slowly reduced, the reduction is made on both sides of the valve equally, but this can only be accomplished by means of a small valve on the engine placed for that purpose. By this means, if the driver of an engine desire to release the brake from the whole train before leaving it he can by this small valve allow air to flow to both sides of the pistons, restoring equilibrium, under which circum-

stances the brakes come off. We are, ourselves, surprised to see when every emergency may be anticipated by such simple means, that Railway Companies should continue to use arrangements that certainly contain elements of danger, with apparently little to recommend them. Our object, however, is not to pretend to tell Railway Companies what is best for them, as practical experience in working must always prove the best instructor; but we are desirous of ventilating any matters connected with railways, and this having already been commented upon strongly by Col. Rich, should recommend itself to the careful consideration of railway engineers. Vacuum automatic brakes, from their great simplicity, appear to be steadily growing in favour in England, and it is a pity when perfection of working may be secured by such simple means, a little attention should not be given to attain it, and considering how recently they have been introduced, that perfection appears to do great credit to the inventors.

THE RAILWAY RATE FOR COAL TO LONDON, AND THE SOUTH YORKSHIRE AND DERBYSHIRE COLLIERY OWNERS.

WE quote from *The Colliery Guardian* the following:—

The meeting recently held in Sheffield of the South Yorkshire colliery owners and the appointing of a deputation to wait upon the railway companies to urge a reduction in the carriage of coal to London and the south, is a repetition of what has taken place on several occasions during the last five or six years, so far as the Great Northern Company is concerned. But now the position is somewhat changed, owing to the Great Eastern having running powers over the Great Northern Railway *via* the joint line from Spalding to Lincoln, so that the former can now take coal direct from south Yorkshire to London, an achievement that was warmly supported by the colliery owners throughout the West Riding, as they believed it would have the effect of greatly reducing the cost of the carriage of coal to London. And they were fully justified in coming to this conclusion from the promises held out by the Great Eastern on receiving the support of the colliery owners in the endeavours made on several occasions by that company to penetrate the Yorkshire coalfield. So far back as 1864 a line was promoted from Peterborough to Doncaster by the Great Eastern Company, and as the estimated cost of the single line was only to be £12,000 a mile, it was stated that the coal would be carried by it direct from South Yorkshire to London at 3s. per ton less than was charged by the Great Northern. Several colliery owners gave evidence in support of the Bill, but the low cost of construction and the proposal to carry coal at such a low rate was fatal to it, as the Committee held that such a cheap line running almost parallel with the Great Northern would be unfair towards the latter, which had been a most expensive one. The Bill was consequently thrown out in the committee room. In 1871, the Great Eastern again attempted to reach the West Riding, this time by a single line for the conveyance of coal only by a line from Long Sutton to a point on the Manchester and Sheffield Railway. As the gradients were only in 1 in 400 the cost of the line was estimated at only £6,000 a mile, and the company offered to have a clause inserted by which they would carry the coal from South Yorkshire to London at a farthing per ton per mile. This was successfully opposed by the Midland and Great Northern Companies, who had been engaged in fighting what was then termed "The Battle of the Rates," and both carrying coal to London at 3s. 4d. per ton less than they are now doing, the charge from South Yorkshire by the Great Northern having been only 4s. 11d. per ton instead of 8s. 3d. per ton as at present. In 1873, another line was brought forward jointly by the Manchester and Sheffield and the Midland, to go from Doncaster to Rushton in Northamptonshire, where it would join the Midland. This was opposed by the Great Northern, as well as by Mr. Chaplin, M.P., and other large landowners, and successfully. Then the Great Eastern again came forward, when a compromise was come to between the company and the Great Northern resulting in the construction of the joint line, which takes the Great Eastern to Lincoln, and gives it running powers over the Great Northern to Doncaster. The colliery owners of South Yorkshire were the warmest allies of the Great Eastern in its costly struggles to reach the West Riding, and now that it has succeeded in doing so, with some reason they look for a reduction of the existing rate formerly promised them, although the conditions are not exactly the same. The Great Eastern, no doubt, would be willing enough to make a reduction, and so in all probability would be the Great Northern; but were they to do so, then the Midland would make a similar reduction from Derbyshire in particular, so as to maintain the present difference of 1s. 1d. per ton in favour of the latter county, owing to its being so much nearer to London. It was for this that the great battle took place in 1871, and in all probability the Midland in its own interest, and in that of the Derbyshire colliery owners, would again adopt a similar course under

the same conditions. This would place the Great Northern at a great disadvantage, seeing that besides being connected with the South Yorkshire district it is also connected with Derbyshire by its line from Derby to Nottingham, on to which a good deal of coal is put for London and elsewhere, so that it would have to make a reduction at both ends of the Midland coalfield. But the colliery owners of Derbyshire and Nottinghamshire lately sent a deputation to the directors of the Midland asking for a reduction of the rate to London so as to place them in a better position to compete with the North country colliery proprietors sending by sea, and who only pay from 3s. 10d. to 4s. per ton by screw steamer from the Tyne to the Thames. Under such circumstances the time appears opportune for a reduction of the rate by the Midland, Great Northern, and the Great Eastern Companies, for one cannot well do it without acting with the others. As the rate by the two latter lines is about one half-penny per ton per mile, and as Mr. J. Allport, in his evidence before a Parliamentary Committee, stated that the cost to the railway companies for carrying coal was less than one farthing per ton per mile, there is a good margin left for making a reduction. The Midland directors had promised to give the application made by the Derbyshire owners the consideration it deserved, and the meeting of the South Yorkshire colliery owners this week was looked forward to with no ordinary interest, not only as regarded the South Yorkshire coalfield but that of Derbyshire and Nottinghamshire as well. It may be said that a reduction of 10d. per ton, which it was believed the railway companies would be warranted in granting, would make a difference of £10,000 a year to Clay Cross, £7,000 to Eckington and Grasmoor, and fully £5,000 a year to several other colleries in Derbyshire, and would also relieve several others in South Yorkshire to the extent of from £2,000 to £4,000 a year. Unfortunately, these hopes have not, up to the present, been realized. The adjourned meeting of colliery owners was held at Barnsley on Wednesday the 14th ult., under the presidency of Mr. A. M. Chambers, of the Thorncliffe Collieries. There was a full attendance, about thirty collieries being represented. The deputation, had, however, nothing to submit. They reported that they had waited upon the directors of the Great Northern Railway Company and laid before them the serious state of trade in the West and South Yorkshire districts. The chairman of the railway company had promised that the matter should have the most careful consideration of the board of directors, but no reply had been received to the request preferred by the deputation for a reduction in the rates. Nothing transpired either in reference to the Midland Railway Company. As the deputation had not received any answer the further consideration of the subject had to be deferred until an adjourned meeting, which it was agreed should be held at the same place on July 10th. It is to be hoped that by that time some definite and satisfactory proposal will have been received from the railway companies.

There appear to be in America some dangers in railway travelling, to which we are happily not so accustomed in England. In *The Railway Review* we are told how some train-wreckers were foiled on the Shore Line railway, between New Haven and New London, Wednesday morning, by a brave station agent. While walking the track, Station-Agent Way, of East River, discovered three men placing obstructions on a bridge. Ordering them to desist, he was attacked by others hitherto concealed, who hit him with a stone and shot him in the arm. The wreckers then fled, and Way ran to the station and signalled an approaching train in time to stop it near the bridge. The obstructions were removed and the train went on, when the wreckers again appeared and replaced the obstructing ties. Again Way signalled another train just in time to save it from destruction.

In our April number we described and illustrated (Plate CXLIV., Fig. 16), the Joy Valve Gear. We quote from *The Railway Review* the following notice of a test of this gear. "The Baldwin Locomotive Works will shortly deliver to the Northern Pacific Railway Company two engines equipped with the Joy Valve Gear, recently described and illustrated in the *Review*. The Northern Pacific is to make a regular test of these two engines (one of which is an 18 × 24 inch mogul and the other a 17 × 24 passenger), as against two new similar engines equipped with the shifting link."

(*Continued from page* 155.)

1	2	3	4	5	6	7	8	9	10	11	12	13
									Analysis.			
No. of Piece.	Makers.	Application.	Year made.	Modulus of Elasticity. Kg. per sq. mm.	Limit of Elasticity. Kg. per sq. cm	Breaking strength. Kg. per sq. cm.	Contraction of Area per cent.	Elongation in 25 cm. (10 in.) per cent.	Carbon per cent.	Sulphur per cent	Phosph. per cent.	Remarks.
130a	Grillo, Funk & Co., Schalke.	Charcoal loco. boiler plates, 12mm. lengthwise.	1876	—	—	4230	34	20.6		0.00	0.082	Very fine layers, light and dark in streaks. Slight arsenic.
130b	ditto	ditto	1876	—	—	4200	30	16.9				As last, flaws outside.
130c	ditto	ditto, cross-wise.	1876	—	—	3890	29	10.9				As before, somewhat rougher.
130d	ditto	ditto	1876	—	—	4310	27	14.7				As last.
130e	ditto	ditto, length-wise.	1876	—	—	—	—	—				Bent cold to 90°, hot to 105°.
130f	ditto	ditto	1876	—	—	—	—	—				Do. 90°, do. 88° (slight cracks outside). (cracked).
130g	ditto	ditto, cross-wise.	1876	—	—	—	—	—				Do. 90°, do. 106° (as last). (perfect).
130h	ditto	ditto	1876	—	—	—	—	—				Do. 88°, do. 92° (as last). (cracked at corner).
39a	Gutehoffnungs-Hütte, Oberhausen on the Ruhr.	Boiler plate 16mm, lengthwise.	1877	2 067 000	1350	3770	14			0.03	0.180	Dark grey, rough, crystalline spots. Very slight arsenic.
39b	ditto	ditto	1877	2 050 000	1480	4000	12	9.3				Very fine layers, dark, with some crystalline spots.
39c	ditto	ditto, cross-wise.	1877	2 096 000	1590	3490	2					Rough crystalline spots, badly welded layer in fracture.
39d	ditto	ditto	1877	2 084 000	1470	3920	3	3.1				Fine layers, at one side one-third quite crystalline.
39e	ditto	ditto. length-wise.	1877	—	—	—	—	—				Bent cold to 12°, hot to 57°.
39f	ditto	ditto	1877	—	—	—	—	—				Do. 14°, do. 83°.
39g	ditto	ditto, cross-wise.	1877	—	—	—	—	—				Do. 8°, do. 48°.
39h	ditto	ditto	1877	—	—	—	—	—				Do. 9°, do. 43°.
69a	ditto	Smoke-box plate, 13½mm. lengthwise.	1877	2 120 000	1300	3180	10	8.8		0.05	0.238	Exceedingly fine layers, with some crystalline spots. Slight arsenic.
69b	ditto	ditto	1877	2 119 000	1430	3440	14.5	9.0				As last.
69c	ditto	ditto, cross-wise.	1877	2 137 000	1670	3240	10	7.0				As before, somewhat rougher.
69d	ditto	ditto	1877	2 116 000	1670	3120	12	5.7				As before, with large crystalline streaks.
69e	ditto	ditto, length-wise.	1877	—	—	—	—	—				Bent cold to 36°, hot to 63°.
69f	ditto	ditto	1877	—	—	—	—	—				Do. 47°, do. 68°.
69g	ditto	ditto, cross-wise.	1877	—	—	—	—	—				Do. 36°, do. 58°.
69h	ditto	ditto	1877	—	—	—	—	—				Do. 38°, do. 59°.
32a	Peter Harkort & Son, Wetter on the Ruhr.	Boiler repairs, 14 mm. lengthwise.	1876	2 157 000	1330	3440	17			0.02		Marked layers, dark grey, lighter towards outside, badly cracked outside.
32b	ditto	ditto	1876	2 074 000	1330	3700	20	8.0				Exceedingly fine layers, with some crystalline spots, outside cracked some distance from fracture. Broke outside the 25 cm.
32c	ditto	ditto, cross-wise.	1876	2 083 000	1140	3170	6					Light and dark grey in marked layers, short and rough fracture.
32d	ditto	ditto	1876	2 159 000	1410	3320	4	2.0				Much rougher than 32b, a few crystalline points.

1	2	3	4	5	6	7	8	9	10	11	12	13
									Analysis.			
No. of Piece.	Makers.	Application.	Year made.	Modulus of Elasticity. Kg. per sq. mm.	Limit of Elasticity. Kg. per sq. cm.	Breaking strength. Kg. per sq. cm.	Contraction of Area per cent.	Elongation in 25 cm. (10 in.) per cent.	Carbon per cent.	Sulphur per cent.	Phosph. per cent.	Remarks.
32e	Peter Harkort & Son, Wetter on the Ruhr.	Boiler repairs 14 mm., lengthwise.	1876	—	—	—	—	—				Bent cold to 33°, hot to 95°.
32f	ditto	ditto	1876	—	—	—	—	—				Do. 57°, do. 95°.
32g	ditto	ditto, cross-wise.	1876	—	—	—	—	—				Do. 16°, do. 73°.
32h	ditto	ditto	1876	—	—	—	—	—				Do. 23°, do. 54°.
78a	Hirsch & Co., Mainz.	Smoke boxes 10 mm., lengthwise.	1876	—	—	1680	0.0	0.0				Broke suddenly and short. Rough layers, quite crystalline on one side.
78b	ditto	ditto	1876	—	—	2590	1	0.6				As last.
78c	ditto	ditto, cross-wise.	1876	—	—	2870	8	2.2				Fine layers, well closed up.
78d	ditto	ditto	1876	—	—	2860	4	1.5				Not quite so fine, or so well closed up.
78e	ditto	ditto, length-wise.	1876	—	—	—	—	—				Bent cold to 13°, hot to 56°.
78f	ditto	ditto	1876	—	—	—	—	—				Do. 9°, do. 71°.
78g	ditto	ditto, cross-wise.	1876	—	—	—	—	—				Do. 10°, do. 42°.
78h	ditto	ditto	1876	—	—	—	—	—				Do. 8°, do. 56°.
31a	Hörde Mine and Forge Co.	Workshop uses 10 mm., lengthwise.	1877	2 036 000	1710	3340	11			0.005		All series 31 was of known good quality. Fine layers, some short and crystalline.
31b	ditto	ditto	1877	2 036 000	1580	3290		4.7				Rough layers with several crystalline streaks; cracked outside. Broke in jaws.
31c	ditto	ditto, cross-wise.	1877	2 038 000	1580	2940	94.5					Rough layers, short with crystalline spots.
31d	ditto	ditto	1877	2 000 000	1080	2920	3	1.3				As last.
31e	ditto	ditto, length-wise.	1877	—	—	—	—	—				Bent cold to 20°, hot to 72°.
31f	ditto	ditto	1877	—	—	—	—	—				Do. 24°, do. 74°.
31g	ditto	ditto, cross-wise.	1877	—	—	—	—	—				Do. 19°, do. 68°.
31h	ditto	ditto	1877	—	—	—	—	—				Do. 12°, do. 71°.
122a	ditto	Boiler plate 14 mm., lengthwise.	1877	2 069 000	1240	3550	—	6.6				Series 122 was of a brand long used, and in general satisfactory. Fine layers, somewhat flattened. Broke in the jaws.
122b	ditto	ditto	1877	2 066 000	1240	3510	—	4.9				Similar, some crystalline spots. Broke as last.
122c	ditto	ditto, cross-wise.	1877	2 078 000	1240	3500	11	6.1				As last, some crystalline spots, and bad weld going through.
122d	ditto	ditto	1877	2 146 000	1330	3030	10	4.8				Fine layers, well closed up, with crystalline layer at edge.
132a	ditto	Best-best charcoal loco. boiler plate, 15 mm., lengthwise.	1876	2 091 000	1550	3420	19	13.0				Very rough, light and dark streaks, with some crystalline spots.
132b	ditto	ditto, cross-wise.	1876	2 076 000	1220	3530	22	11.2				As last, but without spots, cracked outside.
132c	ditto	Loco. boiler plate, 15mm., lengthwise.	1876	—	—	—	—	—				Bent cold to 37°, hot to 69°.
132f	ditto	ditto	1876	—	—	—	—	—				Do. 65°, do. 93°, (cracked).
132g	ditto	ditto, cross-wise.	1876	—	—	—	—	—				Do. 14°, do. 47°.
132h	ditto.	ditto	1876	—	—	—	—	—				Do. 12°, do. 44°.

RAILWAY SIGNALLING.

INTERLOCKING POINTS AND SIGNALS.

(*Continued from page* 151.)

RE-ADVERTING to the plan of the Newcastle Central Station given in our last issue, we would observe that the arrangements of the roads are not given as examples of economical utilization of ground. It will be at once obvious that such detail considerations are of vast importance, especially in and about London, or extensively populated districts, where the land is at a great premium.

Later on we shall have occasion to refer to arrangements of extensive termini, where such economy combined with efficiency has been cleverly attained.

The following table shows the different types of interlocking apparatus at present in use on the North Eastern Railway.

Inventors and Makers.	No. of Frames.	No. of Levers.
Messrs. Stevens & Sons ...	280 ...	4,428
Tweedy & Co.	45 ...	864
Saxby & Farmer	35 ...	436
Easterbrook & Co.	13 ...	172
Janson & Sons	9 ...	129
Yardly & Smith	4 ...	80

The above statement shows that Messrs. Stevens & Sons' appartus is principally adopted on this line, in fact, as fast as the other frames wear out, they are being replaced by those of the above makers. It seems almost unnecessary to add that the simplicity and excellence of this firm's manufactures are of such long-standing reputation that the efficiency of their arrangements require no comment.

The point locks used by this company are those invented by Mr. T. E. Harrison, C.E., chief engineer of the line, and which have been fully described and illustrated in our January number (Plate CXXXIII.).

There are some other special arrangements of minor importance peculiar to the line which we shall have occasion to refer to at some later date.

On Plate CLVIII., Fig. 251, we illustrate an interlocking apparatus as recently designed by Mr. George Edwards, of the Railway Signal Company near Liverpool, and manufactured by this company, now extensively adopted by the Lancashire and Yorkshire Railway Company. Upon referring to the drawing very little further description will be required.

L are the points and signal levers arranged to work in the usual framing *l* in the ordinary manner. The necessary lateral reciprocating motion is imparted to sliding locking bars *s* by means of inclined pieces *I* fixed to the bars *E*. *D* are the motion plates in connection with the levers, provided with slots having inclined terminations, as shown in the detail at Fig. 251*a*, which work "jumpers" or vertical reciprocating bars *E*, carrying locking projections *e*. It will be noticed that by the nature of the slot in the motion plate *D* the vertical bars *E* receive either an upward or downward motion at the termination of its forward or backward stroke.

The usual locks, studs, or stops are riveted on the faces of the lateral sliding bars *s*, which pass under or against those on the bars *E*, so as to effect the necessary locking.

The whole of the locking gear is situated below the frame, and is therefore not so accessible or convenient as in such arrangements as Messrs. Saxby & Farmer's or Stevens & Sons' apparatus, in which all the parts are situated above the floor.

The actual principal involved in this last described arrangement of locking is very old, although the combination of parts may be slightly different in detail.

Adverting to the apparatus employed by the Midland Railway Company there is nothing very special to remark, further than as before mentioned, that all their signalling appliances are designed by their own engineers and manufactured at their own works at Derby.

The Midland Railway Company are now using two kinds of locking frames, which are known by the names of "catch-bolt lock" and "lever lock;" in the former the catch bolt (which holds the signal or point lever in position) locks or unlocks one or more of the point or signal lever catch bolts, and in the latter case the lever itself (instead of the catch bolt) locks or unlocks other levers.

The mechanical arrangement of the locks and connections is very similar in both frames, the only difference being that the lock or tumbler acts upon a projection by the side of the catch bolt in one case and upon the front of the lever in the other; the locks or tumblers are placed between the levers, and are connected in front of them by a bar of sufficient length to reach from one lever to all others that require to be locked or unlocked, the number of connecting bars in one frame of course depends upon the simplicity or the intricacy of the locking required to be effected. It may be mentioned that this railway company have paid royalties to the firm of Messrs. Saxby & Farmer for the locking frames that have been constructed on the "spring catch-bolt or rod locking" system.

Figs. 252 to 256 illustrate an hydraulic interlocking apparatus, as recently designed by Mr. J. C. Brush, of the Midland Great Western Railway of Ireland. Of course, as is well known to most of our readers, there is nothing novel in the general principle here involved, it being now more a question of good design and mechanical efficiency in detail arrangements.

In this apparatus before us these points seem carefully considered, although it is too early to give our readers any practical information as to its actual performances. The

advantages of the use of fluid pressure for working railway points and signals has, (under certain conditions,) been long recognized, both as a means of reducing the manual power required, and for the convenient transmission of such power to great distances.

In Mr. Brush's apparatus these objects are ingeniously achieved by the employment of hydraulic power, exerted on pistons working in cylinders, provided with suitable valves and connections so as to effect the transmission of power to the source required in a simple and reliable manner.

The necessary interlocking of the operating levers for preventing the conflicting actuation of signals is attained by causing the valve spindles to be controlled by sliding locking bars.

Fig. 252 represents a front elevation of a point and signal interlocking apparatus of five levers. Fig. 253 is a sectional elevation. *A* is a cylinder, suitable for use with fluid under high pressure, and fitted with a piston *B* and plunger *C*. *D* is a passage open at all times to such fluid ; and *E* is a passage at the opposite end of the cylinder, sometimes open to the pipe containing the fluid under pressure, and sometimes open to the waste pipe. *F* is a spindle to be rotated by hand, and having fixed on it eccentrics or cams F^1 and f^2. These eccentrics or cams are arranged with their throws in opposite directions, and actuate spindle valves g^1, g^2, the former opening and closing the pressure supply pipe *H*, while the latter opens and closes the waste pipe *J*. These spindle valves are also provided with springs, as shown, of sufficient power to close the valves against the pressure fluid. To the crosshead *K* of the plunger *C* the levers for working the points and signals are attached. It will be observed that the whole of one side of the piston is exposed to the fluid under pressure, whereas on the other side the pressure is only effective on the annulus formed between the circumference of the piston as an outer diameter, and that of the plunger as an inner diameter.

In order to prevent conflicting signals being given, the valve spindles *F* are provided with suitable apparatus as follows, (see Fig. 255). Each valve spindle *F* has an eccentric or cam *F* fixed on it, and the locking bars have lugs, or straps F^2 engaging with the eccentric or cam, by means of which the said bars are caused to traverse in a horizontal direction. The locking bars are also provided with slots in suitable positions relatively to certain stops on the valve spindles. It will be seen on reference to the diagram that the stops M^1, M^2, M^3, are free to move in the slots provided in the bars 20, 30, 40, when those bars are in the positions indicated. It will also be observed that the locking bar 10 is free to reciprocate longitudinally with respect to the stops on the spindles 3 and 4. After the longitudinal motion of the bar 10 has taken place, solid portions of the bar arrive above the stops on the spindles, 3 and 4, and any further forward rotation of those spindles is prevented. It will be seen that the other bars effect similar results. It will also be readily understood that by fixing the stops in their proper positions normally (as, for instance, the stop on spindle No. 2 engaged in bar 30) a spindle may be locked until unlocked by some other spindle moving that locking bar (that is to say, in the present case No. 3 in bar 30) ; similarly, when the eccentric on No. 4 valve spindle is turned to the position represented by the dotted circle it presents a stop to bar 50 ready to be locked by a subsequent forward motion of that bar.

In order to prevent any valve spindle being worked until a full stroke of the hydraulic plunger has been completed, secondary check locking mechanism is employed. For this purpose a lever *N* is mounted on a centre N^1, and attached at one end to the crosshead of the plunger. The other end of this lever is provided with a wedge-shaped piece *O*, which raises a sliding bar *P* in suitable guides, which sliding bar is returned to its normal position by the action of a spring or weight on the withdrawal of the wedge piece *O*. This part of the apparatus will be more readily understood on reference to the sectional detail view, Fig. 256. Bar 10 has two lugs *Q*, *Q*, on one of its faces, between which the bar *P* slides vertically, which motion it derives from the action of the wedge-shaped piece *O*, already referred to. The bar *P* is also provided with a guide *T*. When the vertical bar *P* is in the position shown in Fig. 253, the lugs *Q*, *Q*, on bar 10 are free to pass through the notch P^1 in the bar *P* ; but when the bar *P* is partly or wholly raised by the wedge-shaped piece *O*, a solid portion of it is presented to the lugs *Q*, *Q*, and prevents the spindle which actuates locking bar 30 from being rotated, by reason of the eccentric belonging to it being confined between the lugs, or straps F^2 of the locked bar 30. In a similar manner movements of the other valve spindles may be controlled.

At Fig. 254 is shown the method adopted for preventing the valve spindles being moved in a reverse or wrong direction. On each valve spindle *F* is fixed a collar having two notches R, R^1, on opposite sides. Springs *S* are also provided which engage with these notches, and when so engaged prevent the valve spindles being rotated backwards.

Some few years back Messrs. Hodgson & Imray devised an interlocking apparatus to be somewhat similarly operated and controlled, the fluid pressure employed as the motor in this case, being compressed air. The elements of the apparatus were of the usual and well known type, but the actual operation of the points and signals was pneumatically effected, by making the necessary movements compress the air for working the points and signals and so arranged as to also open or close cocks or valves on the pressure supply pipes. The mechanism operating such cocks or valves being conveniently interlocked.

We have previously called attention to the importance of careful inspection and frequent lubrication of all moving parts of signalling appliances and therefore at Fig. 257 give a novel table of signs adopted by the Great Southern and Western Railway of Ireland as employed on the "chargeman's" visiting sheet to indicate definite work set apart for certain days.

The sheet is ruled vertically for the number of days in the week and longitudinally for the names of stations to be visited on certain days for the above purposes. According to the sign and its position the chargeman learns in a very simple manner the work to be done, its nature, locality, and the day for its performance. The signs and their meanings are explained on the Plate.

In concluding our remarks on "Railway Signalling" for this month's number, we would call the attention of those of our readers interested in this subject, to the "Life Protection Exhibition" just opened at the Alexandra Palace, London, N.

The great interest and importance of the exhibition generally, will be readily appreciated, and the railway section is particularly strong and well worth a visit by all interested in railway safety appliances. Messrs. Saxby & Farmer are exhibiting some magnificent apparatus of a unique character, covering an area of upwards of 2,000 square feet. Many of our chief railway companies are extensive exhibitors; the union of the lock and block systems and continuous and automatic brakes being amongst those of greatest interest. About 8,000 square feet of the exhibition is devoted to railway appliances, and we hope that during the month it is open to the public many will take an early opportunity of visiting it. (*To be continued.*)

THE EAMES DUPLEX AUTOMATIC BRAKE.

IN this age of railway travel the grand desideratum to be attained, and which should be subordinate to all others, is safety. Every appliance to insure that end is one in which all, to a greater or less degree, are interested. The horrors of a collision on the rail float through the mind of almost every traveller, even though surrounded by the luxuries and comforts of the parlour-car, and he who can reduce the danger to the minimum is entitled to be hailed as a benefactor of the race. Consult the records, and it will be found that the causes which result in accidents, in the majority of cases, are due to defective appliances for controlling the train, and hence the brake question is one which assumes gigantic proportions in connection with railway management. For many years the inventive genius of mankind has been directed to the perfecting of the system, and many have been presented to the public, and have been laid before our readers. We now illustrate and describe that known as the "Eames' Duplex Automatic Vacuum Brake," which presents such valuable points of improvement that we heartily commend the same to the attention of the public.

The Eames Duplex Automatic Vacuum Brake is now offered to the public as the embodiment of the most desirable features so long wanted in a successful continuous brake. As its name indicates, it is a vacuum brake, having all the simplicity of that system with its perfect ease of action. The word Duplex also indicates that there are really *two* brakes combined, but, unlike most duplex systems of machinery, each part or each brake is separate from the other, and, while each works separately, they may be used together with the best results. One of these separate brakes is a simple vacuum, acting by the direct exhaustion of the air, and in that form it will readily interchange with any other simple vacuum brake requiring simply a uniform hose coupling. The other brake is an automatic vacuum, and in that form it more perfectly complies with the conditions laid down by the Board of Trade than any other. It is capable of making a quicker stop, when desired, than any other known brake. Should any accident occur to the train, separating it, or in any way injuring the brake, it at once pulls up both sections of the train. Should the accident be such as to completely disable the automatic brake, the driver can readily release it, and the train can then proceed with an efficient simple vacuum brake for the remainder of its journey. Injury to the rubber diaphragms under any of the carriages does not effect the efficiency of the brakes on the rest of the train, and either system of pipes on the train (the simple or the automatic) may be ruptured without imparing the efficiency of the other system. In short, the automatic and the simple brake may be used jointly, or either may be used independently of the other. The usual stops are made with the greatest ease, and without any shocks, jars, or shaking, by the use of the simple brake. Should it be found by the driver that for any cause, either a miscalculation of the speed, the distance, the state of the rails, or from the possible failure of the simple brake, he will overrun his stopping point, he still has ample time and distance in which to pull up, by the powerful automatic brake, a simple and slight further movement of the brake handle being all that is required to bring the full power into instant use. Mechanically, it is simpler than other brakes. There is no place in it where even a single drop of oil is ever required. There are no nicely adjusted sliding pistons, valves, or other devices requiring constant attention and adjustment. There is no friction about the devices on the carriages, and no attention required to be lavished on them. In fact, a carriage may be left exposed to the weather for twelve months, and the brake arrangements found to be in perfect order upon the carriage being attached to a train.

DURABILITY.—The only part liable to wear out and requiring renewal is the rubber diaphragms and hose connections. The reports of the New York Elevated Rail-

way show that the average life of a diaphragm under a car is 200,000 stops, equivalent on a surface railway, like the Midland or Great Northern, to a constant daily use of over *twelve years;* and the report of the trial of October 6th, 1881, of this brake on the Great Northern Railway shows that the complete destruction of two-fifths of all the diaphragms on the cars of the train will still leave the brake efficient.

Certainty of Action.—The appended report (marked *A*) of George V. Morford, Assistant-Superintendent New York Elevated Railroad, shows that 69,277 stops are made with the Eames Brake each working day on the Elevated roads, *more than* 2,000,000 *in each month*, which are more stops than are made by all power brakes of any kind in the entire United States in the same time. This has been the only brake in use on that line since 1878. It is also adopted by the Callao, Lima, and Oroya Railroad, in Peru, South America, where the railroad crosses the Andes at an elevation of 15,645 feet, or nearly three miles vertically above the sea, with a continuous ascent from the sea to that height in 104 miles. [Report appended, *marked D.*] And in nine different countries of the globe, and on upwards of ninety lines of railway, and after seven years of more severe duty than that ever performed by any other brake, it stands, without one single failure, a record at once unapproached and unapproachable of durability and certainty of action.

Cost.—The price of the Eames Duplex Automatic Brake is 25 per cent. less than any other single automatic brake; and considering that *two* efficient brakes are complete on every train, the advantage in price over others is vastly greater. The feature of *double security* and *double efficiency* is fully secured by the Eames Patents. The cost of maintenance is less than half that of others.

[REPORT A.]

New York, *January 8th*, 1881.

Fred. W. Eames, President Eames Vacuum Brake Co., Watertown, New York.—

Dear Sir,—Herein please find a carefully compiled statement of stops made by the use of the "Eames Vacuum Brakes," on the separate lines of the Manhattan Elevated Railway Co., together with recapitulation.

Stops Made Each Week Day.

	2nd Ave	3rd Ave.	6th Ave.	9th Ave.	G. C. and 34th St. Branches.
By Regular Trains ...	12,476	14,828	16,142	8,820	884
By Switching Trains ...	1,395	1,685	1,970	1,470	
By Switching Engines ...	2,232	2,359	3,546	1,470	
Total	16,103	18,872	21,658	11,760	884

Recapitulation.

Stops, Regular Passenger Trains, all Lines	53,150
,, ,, Switching ,, ,, ...	6,520
,, ,, ,, Engines	9,607
Total Stops	69,277

Geo. V. Morford.
Late Assistant Superintendent.

Practical men have been much divided as to the relative values of automatic and non-automatic brakes, but we think there can be no question that an automatic brake (*if it be reliable*) is the better, and upon the point of reliability the whole question turns.

Although the brake we now illustrate has only been in use in England during the past four years, it has been in regular work in America, North and South, and in Europe for seven years, and during the whole period we have not seen any record of failure.

On the 6th October a special train was run from Leeds to Adwick Junction (Barnby Don Branch) and back, trial trips being made on the Barnby Don Branch, beyond the junction above referred to. The train was composed of Lancashire and Yorkshire Railway Company's engine and carriages, fitted throughout with the Eames continuous brakes. The experiments were conducted under the personal supervision of Mr. F. W. Eames, of Watertown, New York, the inventor of the brake. The revolutions of the van wheels were read on an instrument specially fitted for the purpose. The speeds were read from a Stroudley's Indicator, which had been carefully adjusted before the first trial, and the times were taken by chronographs. These times were taken by Mons. Soulerin, Mr. Gresham, and Mr. Campin, and in no case was there a variation of more than 1-5th of a second in the readings. The engine was a light tank engine, drawing four carriages and van. The total length of the train, exclusive of the engine, was 147 feet. The brakes were drawn completely back at a vacuum of 16½ inches of mercury. When running a vacuum of 21 inches was recorded in the gauges connected with the automatic pipe, but on the application of the brakes the vacuum fell to an average of 10½ inches of mercury, and under such circumstances it will be observed that the stops have been exceptionally favourable. In the last three trials the elastic brake sacks were purposely cut through to the extent of ¾ of their circumference. These trials cannot be regarded as fancy or special trials, as the Eames brake had been working on the same train for upwards of two years, and was in ordinary working condition. After the application of the brake the retardation was uniform, no jerking or churning action being felt such as occurs with the fluttering motion of some brakes. It is to be observed that these trials were made with the intention especially of ascertaining the action of the brake under disadvantageous conditions, hence the low amount of vacuum employed in the tests: with higher vacuum the shorter stops usually made would of course be obtained. After the destruction of the two diaphragms above referred to, the machinery was still further mutilated, the only brakes left capable of action being those on one pair of van wheels and those on the engine. The action of the automatic pipe was entirely destroyed, and the hose at the end of the carriages left open, in order to cripple the plain brake pipe. The covers of the check valves in both

ejectors being removed, the check valve was taken out of the small ejector and both covers left off, so that the atmospheric air had free access to both brake pipes; and the diaphragm controlling the steam valve of the large ejector was also taken out, and notwithstanding the mutilation referred to, the train was held under perfect control; this indeed may be considered a crucial test of the Eames brake.

We shall, in a subsequent issue, give a detailed description of the working parts of the system; in this we shall be confined to the general features.

Plate CLVII. Fig. 1, is a general view of ejectors. Fig. 2 enlarged view of trussed brake beam, showing method of hanging the same. Figs. 3 to 7 are cross sectional views of the drivers'-air valve, placed on the engine which controls the whole action of putting on or throwing off both the plain and automatic brake; the automatic will, however, apply itself, should the train separate, or should the guard open the valve under his control, or should any injury occur to the automatic pipe thereby destroying the vacuum. Fig. 8 is a detail of a drip valve to carry off any water formed from the steam condensing in the ejector. The valve, of which sections are shown, is a conical plug valve with ports as indicated, and operated by a straight lever projecting through the cover of case, to which is attached a quadrant having five notches; a catch, held down by a spring attached to the handle, which falls into one of the five notches to hold the valve in place in one of the five positions marked on the quadrant as follows: Rest, On, Full on, Off, Full off. There is a small ejector operating continuously in order to maintain a vacuum in the automatic pipes and vacuum reservoirs throughout the train. In the five sectional views the same letters of reference are used. *A* shows the pipe leading to main ejector, *B* the pipe leading to automatic brake, *C* the pipe to plain brake, *D* the port through plug of valve which is always open to pipe *A*, *E* the air way which connects either *B* or *C* with *A*, according to position of *X* and of air release ports leading to the open air through back of valve.

The main ejector valve is held closed against the pressure of steam in boiler, by a vacuum being maintained over a small diaphragm, which is connected by a lever with the valve. When this valve is to be opened this vacuum is destroyed automatically by admitting air through small ports in valve (not shown in sections), and closed by restoring the vacuum.

In Fig. 5 *REST* is the normal position. *A* is connected with plain brake pipe *C*, the main ejector being closed; but should the vacuum be destroyed in the automatic brake pipe, with which there is connection through port before mentioned (not shown in section), the main ejector will be started, and the plain brake will reinforce the automatic.

In Fig. 4 *ON* shows the position of valve when the plain brake has been applied, the main ejector having been set in action, and the air exhausted through *C* and *A*, and the passage to the automatic pipe being cut off, a vacuum is thus maintained, and the automatic brake does not come into action.

In Fig. 3, *FULL ON* the automatic pipe *B* is in communication with open air through release port *x*, and the vacuum in automatic pipe being destroyed, the automatic brake is applied; the main ejector is also in operation, and through pipes *C* and *A*, and ports *E* and *D*, the plain brake reinforces the action of the automatic.

In Fig. 6, *OFF*, the brakes are released by means of passage *y*, which permits the passage of air into plain brake pipe *C*.

In Fig. 7, *FULL OFF*. This is used to quickly restore the vacuum in the car reservoirs after an automatic stop, by causing the main ejector to reinforce the smaller one, thereby restoring immediately the power of the automatic for further service.

On Plate CLV. is represented the general engine arrangement of this brake, and on Plate CLVI. the general carriage arrangement.

The Eames system can at present be seen in operation at the "Alexandra Palace," where those in charge will afford every facility for its critical examination.

Erratum: The beginning of Mr. Post's article *Improvements in permanent way*, page 145, June number, to be read as follows: "We give the following details of new systems of Permanent Way which merit the attention of railway engineers. We are indebted to Mr. J. W. Post, Permanent Way Engineer, Dutch State Railway Company, for the following article."

"The trial lengths of iron permanent way laid in former years on different parts of *the* system worked by the Dutch State Railway Company," etc.

GREENWOOD'S PATENT CARRIAGE WINDOW SASH HOLDER.

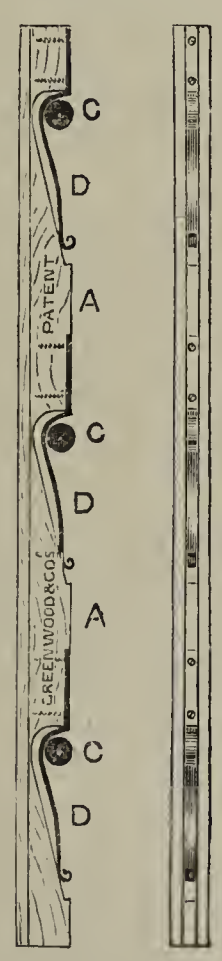
A REMARKABLY, simple and efficient contrivance for holding the window sashes (either glass or Venetian) of railway carriages, tramway cars, omnibuses, road cars, cabs, or private carriages, at any desired height without the aid of the straps and buttons, counterweights, or springs at present in general use.

It is the invention of Messrs. Greenwood & Co., of 115, Victoria-street, Westminster.

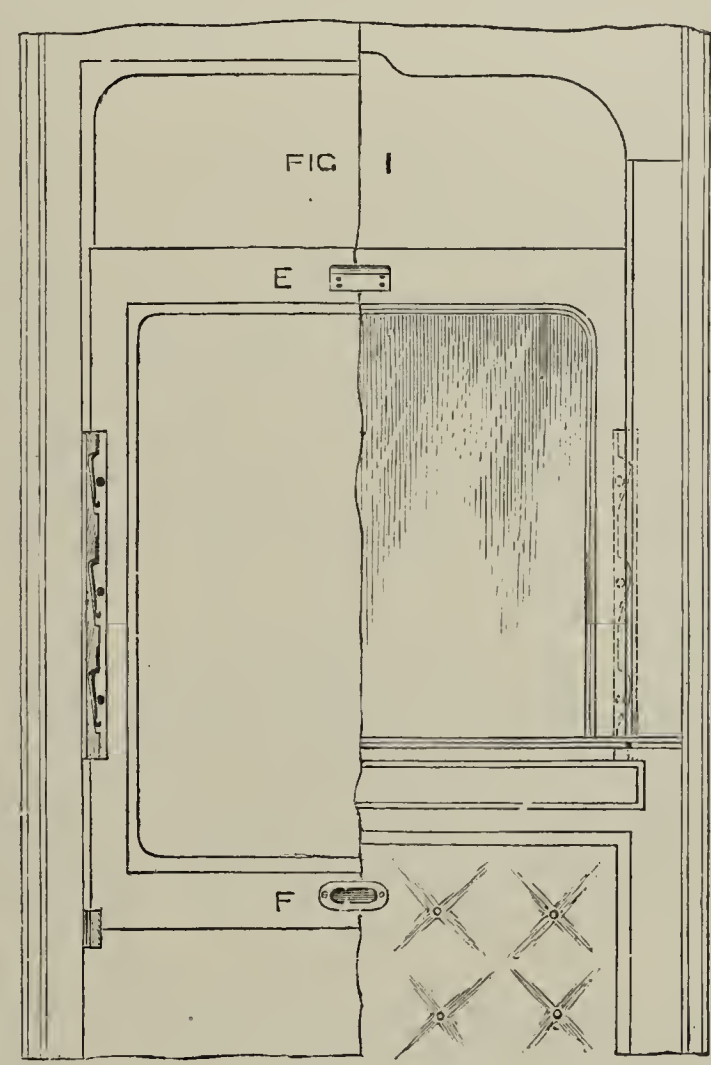
The following are some of the advantages claimed :—No lace strings, straps, buttons, or counterweights required. Prevents the very disagreeable noise of rattling. Cannot be tampered with. Will not slip down with the vibration of the carriage. Will allow of the sash being put over the fence plate or rail on to the cill. Prevents glass getting broken from sudden fall of window. Prevents the sash frame from getting twisted or joints started from the same cause. Is not expensive in first cost, and effects an enormous saving in maintenance. Is easily applied to either new or old carriages. Can be readily adjusted to suit any weight of window. With the aid of accompanying drawings the apparatus may be thus briefly described :—

FIG. 3

FIG. 2.



A groove B B (Fig. 3) is cut in *each side* of the sash, *about* 15 in. long, $\frac{5}{8}$ in. deep, and $\frac{5}{16}$ in. wide, and a transverse groove of corresponding length $\frac{1}{4}$ in. deep, and the full width or thickness of the sash. Into this groove the three metal rollers (C, C, C) are placed at intervals corresponding to the slanting notches of the friction slide (A A), which is then inserted with its notches downwards, the wide part of them being towards the *top* of sash, and the rollers at the *top* of the notches, as shown in Fig. 2. The sash holder is then *flush* with the sash. The sash is then lowered into the frame, and the rollers immediately roll down the inclined planes to the narrow part of the notches, thrusting the friction slides against the door frame or pillars, as shown in Fig. 1.



Sufficient friction is thereby created to hold the sash in position, and although no vibration of the carriage can move it, yet the mere pressure of the hand upon the projecting finger-lift E (Figs. 1 and 4) is sufficient to overcome the friction and slide the window down to any desired point.

The action of raising the sash moves the rollers to the top or wide part of the notches in the friction slides, thus

FIG 4
PROJECTING FINGER LIFT

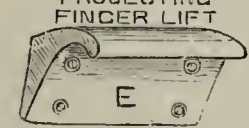


FIG. 6
SECTION OF FLUSH FINGER LIFT

relieving them of all friction against the door frame or pillars.

The sash may thus be left in suspension at any height required, (*to provide for ventilation,*) *without* the disagreeable noise of rattling which is experienced in the old system of hanging the sash on the strap.

For the purpose of putting the sash over the fence-plate or rail into the cill, to keep out rain or snow, &c.; the sunk fingerplate F (Fig. 1 and 5) is provided; which is specially designed to facilitate the pulling back of the sash over the fence-plate or rail for the purpose of lowering it (see F, Fig. 1, and Fig. 6).

It may here be mentioned, that this is the only reliable sash holder that permits of this operation being satisfactorily performed—a very important point, as it excludes wet when raining or when the carriage is being washed down.

The top or projecting finger-lift is also specially designed to facilitate the lowering and raising of the sash, without the necessity of the passenger rising from his seat. (See E. Fig. 4.)

CORRESPONDENCE

RAILWAY BREAKS.

To the Editor of the "Railway Engineer."

Sir,—The *Bund*, the official organ of the Swiss Government, reports that the Public Works Commission of the National Council have expressed to the Council of the Republic their desire to be supplied by the Railway Department with a Report on the following questions:—

What fate is likely to overtake a railway train fitted with a continuous break—

1st—When the said break *fails to act?*

2nd—When the person responsible for its being properly used, either *neglects*, or *is unable to perform, his duty?*

As the subject is one of general interest, not only in Switzerland, but also in every country where railways exist, and as, to meet the increased requirements of the traffic, continuous breaks of some kind or other have become a necessity, it may prove advantageous to consider it with reference to the various principles on which such breaks are worked, and to select for that purpose, the three which are most generally known, namely, Automatic Compressed Air, Non-automatic Vacuum, and Automatic Friction.

I.—*Automatic Compressed Air Breaks.*

The reply to both the above questions has most unfortunately been only too clearly given, with this form of break, by the fearful catastrophe at Blackburn, in August, 1881, because whether, as reported by the Government Inspector, Colonel Yolland, the break *failed to act*, or, as suggested by the Company who had supplied it, *the driver neglected his duty*, the result was the same, and was shown by the mangled bodies of the eight killed and sixty wounded passengers and guards, as well as by the wreck of the trains piled up in wild confusion in the station!

With regard to the dangers arising from the causes referred to in the second question, it is doubtless true that a safe-guard is intended to be provided with this form of break, for, if the guard at the rear of the train satisfies himself, on every occasion, by opening the air-tap on the last vehicle previous to starting, that the main air-pipe is charged with compressed air, he will know, not only that the engine-driver really has control over the whole of the breaks, but that it will also be in his own power, as well as in that of any other guard. (or, even if considered desirable, in that of any passenger) to apply them on remarking that the driver appears "*to be neglecting*, or *unable to* perform his duty."

Unfortunately, however, it is difficult, if not impossible, in practice, to have the precaution here noticed strictly carried out, because, to be really efficient, the test must be repeated after every change in the formation of the train, as well as before starting from the first station, since, as must be remembered, there is at each end of every vehicle, as well as at that of the tender of the engine, an air-tap on the continuous break connection, and that, should any one of these taps be accidentally left closed, the efficiency of all the breaks behind it is completely destroyed.

In such a case, however, *there is nothing whatever to prevent the driver from starting*, and he may, therefore (indeed, as shown by the half-yearly Parliamentary Returns on continuous brakes he occasionally does), so start in the full belief that he has the break-power of the whole train under his command, *whereas, in reality*, if a shunter has omitted to open either tap on any one of the carriages, *only a portion of the breaks are under the driver's control*, whilst if the fireman has neglected the same duty on the tender, *neither driver nor guards have any control whatever.*

A remedy for the inconveniences and possible danger arising from this cause was sought to be obtained by suppressing the air-taps altogether, and by introducing instead automatic valves in the coupling-pipes themselves. It appears, however, to have been deemed possible that the Blackburn accident may have been in some way due to the failure of one of these valves, because immediately after its occurrence, they again were hastily suppressed wherever they had been introduced, and were replaced by the air-taps. *It is evident, however, that the previous difficulty will thus again present itself.*

It results from what has been here pointed out, that the class of breaks now under notice, offers but an imperfect guarantee against dangers arising from the causes named in the questions of the Swiss Commission, whilst another fruitful source of inconvenience and possible risk—which has already produced fatal consequences—consists in the *over-sensitiveness of the automatic arrangement*, by which the whole of the breaks apply themselves and stop the train, on any accidental leakage disturbing the balance of air-pressure in the main air-pipe and reservoirs respectively. This frequently happens in a tunnel or other unfortunate position where the delay required for opening separately each of the escape valves and thus emptying the reservoirs under the carriages is most objectionable, to say nothing of the possible danger of being run into by a following train, where the block system is not rigidly enforced.

II.—*Non-automatic Vacuum Breaks.*

With this class of break there does not appear to be any guarantee whatsoever in either of the cases in question, beyond that which is supposed to be afforded by the hand-breaks of the guards, upon which, however, little or no reliance can be placed, although with this form of break they cannot be dispensed with.

Cases are frequently reported in the half-yearly Parliamentary Returns on Continuous Breaks, where trains have run through stations or past danger-signals, owing to the break failing to act in consequence of the air-pipes having either become uncoupled during the journey, or of their having never been coupled at all, *such an occurrence being only notified to the driver, when too late, by the refusal of the breaks to act*, and that often at a moment when they are most urgently needed.

In the same manner, danger results on the couplings being torn asunder in any accident, *because both portions of the train are then instantly deprived of all break-power*, except that of the hand-breaks. Should the couplings give way whilst the train is on a rising gradient, as happened in the case on the North British Railway, reported on by General Hutchinson in August 1881, the rear vehicles run backwards down the incline into collision with a following train, whilst, in the similar cases, which sometimes (though more seldom) occur whilst descending an incline, the rear vehicles overtake and run into the front portion of their own train.

Various efforts have been made to introduce a really practical Automatic Vacuum Break so as to obviate these dangers, but in reporting on a case which occurred at Cardiff recently, where a collision was caused by the break failing to act, the Government Inspector, Colonel Rich, points out in strong language certain weaknesses inherent in a break of this description.

III.—*Automatic Friction Breaks.*

As the principle upon which friction breaks are worked consists *in utilizing*, as a self-destroying force for controlling the train's speed, *the very momentum resulting from that speed*, it follows that the required force can never be absent when needed, and that consequently, *if a number of perfectly independent apparatus for utilizing it are held in constant readiness to act*, and are so arranged *that they can by no possibility avoid coming instantaneously into play when called upon to do so*, the case of the breaks "failing to act," as suggested by the first of the questions now under review, *never can occur.*

As the Heberlein Breaks are now arranged, this result is ensured by the special construction adopted, whilst the dangers arising from the engine-driver's neglect or inability to perform his duty, are also guarded against by its being placed equally in the power of each guard, (or even of any passenger, if considered desirable,) to apply the breaks on such an emergency.

Unlike the compressed air and vacuum systems, however, these breaks offer the perfectly exceptional advantage that the train *cannot be in motion at all unless this power of control is fully in force*, because the breaks in their normal condition are always on until intentionally taken off, and this, in the case of a train leaving a station, *must* be done by the driver before he can move at all, *the mere fact of his being able to do so being a sufficient proof that everything is in order.*

Perfect automatic action is also inherent in this system and cannot be separated from it, because on the break-cord, which alone prevents the breaks from acting, becoming ruptured by any cause, they infallibly come into operation and stop the train. The over-sensitiveness, however, previously complained of as existing in the case of the compressed air break is here entirely obviated by simply having the strength of the break-cord so much in excess of that necessary for the work it has to perform, that nothing short of an actual separation of the train couplings can affect it.

With respect to the dangers on inclines or rising gradients, noticed in the case of vacuum breaks, it is self-evident from what has been already stated, that no such drawback exists at all with friction breaks, as these invariably apply themselves on the occurrence of any such accident, and remain on, no matter for what length of time, until again taken off, whilst there is no limit to the number of times they can be used in any given period, the power required being ever present, as long as the vehicles are in motion, thus also doing away entirely with the necessity for hand-breaks.

There are obviously many other points in connection with continuous breaks which demand the most careful consideration, and with reference to which the merits of the various systems must be most carefully weighed. I have, however, chiefly confined myself in the fore-going remarks to noticing the special issues raised by the very interesting and important questions of the Swiss Government authorities.

Yours truly,

London, June 26th, 1882. CHARLES FAIRHOLME.

OFFICIAL REPORTS ON RECENT ACCIDENTS.

Major Marindin has reported the result of his inquiry into the causes of a collision which occurred on the 2nd March last, at Stirling Station, on the Caledonian Railway. From the evidence it appears that the North British light-engine (No. 78) passed Craigs crossing signal-cabin at 10 p.m., came to a stand at a point between 50 and 65 yards outside the middle cabin down home-signals, which were at "danger," and waited there until just before the collision took place at 10.18 p.m, at which time it had just commenced to move forward. This engine was going on to the north British line, and it ought to have been signalled forward from Craigs Crossing cabin to the middle cabin by two beats on the bell; but, as no such signal was sent, the signalman in the middle cabin remained in ignorance of its approach. When, therefore, he received at 10.14 the bell-signal for the Caledonian 9.20 p.m. down passenger train, he was not aware that the North British engine was standing outside his down home-signals, and he at once lowered his main line home and distant signals. The Craigs Crossing signalman then lowered his signals for this line, so that the 9.20 train approached the station with all the signals off for it, and was running at a speed of probably about 18 miles an hour when the driver saw the tail-light on the North British engine only a few yards in front of him. He at once applied his continuous brake, and, although there was hardly time for it to have much effect in reducing the speed of the train, it was, by its quick action, probably of considerable value in preventing any telescoping of the carriages, such as would almost certainly have ensued in a similar case with a train running at so high a rate of speed, and with brakes only upon the tender and guards' vans. The North British engine had fortunately just commenced to move forward when the collision took place, and the shock was therefore much less than it would have been if the engine had been stationary. There is considerable discrepancy in the evidence as to the exact distance at which the North British engine was standing outside the home-signals, and as to the conduct of the driver of the engine. He states that he whistled for the proper signal three times,—once on passing Craigs Crossing cabin, once after he came to a stand about 50 yards outside the signal, and once as he was starting forward immediately before the collision,—because the top arm on the signal-post had been lowered, and not the second arm, which was the proper signal for him; but he admits that he gave three *short* whistles upon each of these occasions, whereas it is clearly laid down that for the signal to the North British line three *long* whistles should be given. He also states that when he first stopped he got off to look round his engine, knowing that the proper signal could not at once be lowered for him on account of a goods train being on the up line across the junction; that he then went across the line to speak to the driver of a Caledonian engine which was standing upon a siding; and that he did not stop there more thad two minutes, when, seeing the main line signal lowered, he went straight back to his engine and started at once, giving at the same time three whistles for the proper signal. This statement is clearly most inaccurate, and is not even supported in all respects by the evidence of the fireman, for this man states that his driver gave three long whistles and not three short whistles, and that the main line signal arm was not lowered until his driver was getting up on to his engine. The Caledonian driver, with whom the North British driver was conversing, states that the North British engine came to a stand from 15 to 20 yards farther back than the spot pointed out by the North British driver, and therefore unnecessarily far from the signal; that the North British driver remained talking with him until the main line signal was lowered; and that the whistle on the engine was sounded, presumably by the fireman, while the driver was still standing by his side. It is clear from the statements of the two signalmen in Craigs Crossing cabin and middle cabin, which agree in every respect, that the main line signal was lowered two or three minutes before the collision took place, and therefore this collision would not have occurred if the driver had been where he ought to have been—on his engine—and had at once taken the signal, as he should have done, seeing that it is not unusual to bring North British engines forward on the main line when the junction is fouled by another train. The evidence of two men who were at the Shore Side signal-box, north of the station, would seem to support the North British driver's statements as to his having sounded his whistle for the signal, and I think that if the signalman in the middle cabin had been on the alert he ought to have heard this whistling, although it must be remembered that he had not been warned of the approach of the engine, and had no reason to expect it. The duty of sending the bell-signal for the engine from Craigs Crossing cabin was certainly that of signalman John Booth, who was just leaving duty, for he had received the block-signal for the engine from Bannockburn, and he should have completed the transaction or have told the man who relieved him that he had not done so. This collision was therefore due, first, to the neglect of duty of signalman John Booth in omitting to send to middle cabin the proper bell-signal for the North British engine; and secondly, to the carelessness of the driver of the North British engine, who was evidently gossiping with the Caledonian driver until he was recalled to his engine by his

fireman sounding the whistle, whereas, if he had been attending to his duty, he would probably not have stood outside the home-signal for over a quarter of an hour without again whistling for it to be lowered for him, knowing, as he must have done, that the passenger train was nearly due, and he would certainly have had plenty of time to have run forward when the main line signal was lowered for the 9.20 p.m. passenger train two or three minutes before it actually arrived. I do not think that any blame attaches to the driver of the passenger train; for, although it was possible for him to have seen the tail-lamp on the North British engine for nearly 200 yards before he arrived at the point of collision, if he had been looking for it, yet he had every reason to suppose that the line was clear, and cannot be censured for having had his attention fixed upon the signals, and not upon the line, for the short time which would be occupied in running for that distance at a speed of 18 miles an hour. The best safeguard against the occurrence of accidents such as this would be the extension of proper block-working to the section between Craigs Crossing and middle cabins, and I can see no reason whatever why this mode of working should not be adopted upon this section, and also upon the corresponding section at the north end of the station. It would also give the signalmen a much better chance of seeing an obstacle upon the line if their cabins were raised; for at present the view of the down line from Craigs Crossing cabin is obstructed whenever there are trains in the sidings on the down side of the line, and that from middle cabin whenever there are trains standing on the up line.

Major-General Hutchinson, has reported the result of his inquiry into the circumstances connected with the accident which occurred on the 2nd March last, at the entrance of London Road station, Manchester. The mode of working the facing-points at which this accident happened having been altered from what it had been at the time it occurred (viz., by means of a ground lever) to what it was at the time of the inquiry (viz., by means of a rod moved by a lever in a frame), the evidence is the only means available for endeavouring to arrive at the cause of the accident. Judging from this, and from the fact that the wheels of the dummy-van and brake-van,(the only two vehicles which left the rails) are stated to have been in good order, and true to gauge, the accident was most probably caused by the left tongue of the switches having (from some reason that cannot now be ascertained) slightly opened between the passage over them of the trailing-wheels of the tender, and the leading-wheels of the dummy-van, and so allowed the left wheels of this vehicle, to take the wrong side of the left tongue; the dummy-van having then left the rails, dragging with it the brake-van next to it. The left tongue must then have properly fallen back into its proper position, as the three remaining vehicles composing the train kept the same line of rails as that on which the engine and tender were running. It is very desirable that as little time as possible should be lost in interlocking and providing with proper safety arrangements, these and other unprotected facing-points at the entrance of this important station. The alteration in the mode of working the facing-points took place before it was known that an inquiry would be held, the Company having neglected to make a return of the accident for three weeks after its occurrence.

Colonel Rich has reported the result of his inquiry into the circumstances which attended the accident of a brake-van of a goods train being thrown off the rails, and the subsequent collision of a passenger train with this brake-van, that occurred on the 14th April last, at Marchington station, on the North Staffordshire Railway. The accident of the van getting off the rails appears to have been caused by the train having been pushed back while the van was standing foul of the cross-over road points. The station master who gave the signal for the train to move back, and who worked the points, could not possibly see the exact position of the van at the time that he gave the signal for the train to move back, and he should not have given this signal, before the guard of the train had got out of his van and signalled to him that the van was in such a position that the train could be safely pushed back. The guard was not aware that the train would be stopped at Marchington for the purpose of being shunted, and he was eating his breakfast in the van at the time that the train came to a stand. The subsequent collision of the passenger train with the brake-van which was off the rails, was caused by the points of the cross-over road lying in the wrong direction at the time the passenger train arrived. The points at both ends of the cross-over road are worked on the same lever, but as the points on the down line had been uncoupled from the lever before the collision occurred, this lever might, and ought to have been put back and firmly fixed in the notch, as soon as the disconnection had been made, in which case the up line would have been in a perfectly safe state for the passenger train to run on, and it could not possibly have gone on to the cross-over road and run against the van; but it appears from the evidence that the station master or his wife took the lever that works the cross-over road points out of the notch for the signal-fitter to disconnect it; and I presume it was not put back in the proper position after it had been taken out, for the purpose of disconnection. The evidence of the driver of the passenger train, who stated that the points were changed while he was approaching, would tend to show that the lever had been left in a wrong position, and that the station master or some other person recollecting this, at the moment the passenger train was arriving, went to set them right, but in the haste of doing so, placed them in the wrong notch. I think this engine driver's evidence cannot be relied on. As there was

nothing to prevent the station master at Marchington making the points on the up line thoroughly safe, after those on the down line had been disconnected, he is responsible for the collision, and also for the first accident, as he should not have signalled to the engine driver of the goods train to push back, until the guard of this train had given him the "All right" signal. I think the signal-fitter is also to blame for not seeing that the points of the line on which the passenger trains were being run, were properly secured, while he was at work close to the cross-over road. As the station master stated, that he was talking to Lord Parker, from the time that he took the lever of the cross-over road points out of the notch, until the collision with the passenger train occurred, I wrote to Lord Parker, who could probably clear up the fact deposed to by the engine-driver of the passenger train, "that the points were changed just before the engine reached them," but I have received no reply from his Lordship.

Colonel Rich has also reported the result of his inquiry into the circumstances which attended the collision that occurred on the 25th April last, at Portskewet Pier station on the Great Western Railway. The collision was caused by the vacuum brake failing to act when it was required. These brakes should not be used when trains are running into terminal stations or up to junctions, or into stations where they are required to run up to the same platforms as other trains may be drawn up at, except in cases of emergency. The Company's regulations are not as distinct and decided as they should be on these points. Station-masters and inspectors should be required to report all cases where continuous brakes have been used under such circumstances, so that they may be investigated by the departmental officers, so as to keep a proper check on this misuse of continuous brakes, which if not stopped, will certainly cause accidents. In the present case the engine-driver appears to have been running at the ordinary rate of speed, so that he might have pulled up his train at the pier platform, by calling for the ordinary guard's hand brakes and by using his engine brake. He appears to have touched the lever of the vacuum brake three times slightly, so as to control the speed of his train, as he descended the incline towards the pier; and, at the last moment, when he found that he was running close up to the empty coaches, and tried to stop his train by means of the vacuum brake, which he ought to have been able to do, this brake failed to act. If the driver could have foreseen this, I think the train might easily have been stopped by his whistling in time for the guard's brakes. The engine-driver did not notice the vacuum gauge on his engine, which was behind him, as he was running with the coal bunk of his engine in front. The fireman or either of the guards did not notice the pressure gauges as the train ran from the junction to the pier. From the evidence of the captain of the ferry steamer it appears that the vacuum pipe between the engine and the train was disconnected and placed on the plugs when he observed the train at the pier. If this was done at the junction it would account for the brake not acting, but I have no reason to think that it was done at the junction, and it is possible that this may have been done by the porter, who usually uncouples the engine at the pier, during the excitement which followed the collision, but this man does not recollect doing it. I believe that the brake failed to act, in consequence of there being a very small amount of vacuum in the pipe and cylinders, possibly none, as the train approached the pier, after the driver had applied it three times during the short journey from the junction. I think the efficiency of this brake has been materially interfered with by the hole in the piston rod, which allows it to leak off in a short time. I experimented on the carriages of the 6.40 p.m. train, which were standing at the Portskewet junction when I made my investigation, and I found that the brake leaked off the van, which was next to the engine, in about 30 seconds. It leaked off one of the coaches near the tail of the train in about two minutes; and the brake on one of the other coaches near the centre of the train held for more than five minutes, probably owing to the hole being stopped up. The effect of these brakes is dependent on the extent of the vacuum. While running into Taunton station on the engine of the express train to Plymouth, on the same day after my inquiry, there seemed to be a very considerable leakage in the vacuum brake. The ejector did not rise the gauge beyond 20 inches, and this leaked off to about 7 to 9 inches before the train left Bristol. After leaving, the pump rose the gauge very slowly to about 22 to 23 inches while the train was running, but the whole of the brake power appeared to be exhausted before the train was half stopped when running into Taunton station, so that at that momentous time there was actually no continuous brake available until the vacuum was recreated by the application of the ejector, after which the train was stopped at the platform. I doubt whether this was considered by the engine-driver as a failure of the brake, and would be reported as such; to my mind it was a very important failure.

Major Marindin has reported the result of his inquiry into the causes of a collision which occurred on the 29th April last, at King's Lynn station, on the Great Eastern Railway. This collision was caused by the inexperience of the driver of the Midland engine in the use of a continuous brake. He is an old and steady driver, but he had never driven an engine fitted with a continuous brake until the day before the accident. The steam-brake upon his engine and the vacuum-brake upon the train are applied by the same handle, the first movement of which applies the vacuum-brake upon the train slightly, and not the steam-brake. In this case the driver thought that the vacuum-

brake on the train was under his control, and he intended to stop by a slight application of this brake, but, finding that the first movement of the brake-handle had no effect in stopping the train, he then moved it further so as to apply the steam-brake, too late, however, to stop the train completely before the slight collision took place. If he had been properly instructed in the use of the brake he would have known that the brake-pipe had not been connected up, for this could not have been done until he had shut off the small ejector, and so enabled the coupling pipe on the tender to be taken off the stopper. According to the strict reading of the rules the guard ought to have told the driver what amount of brake power was at his command, but it does not appear to be the practice to do so except when an engine is changed upon a journey. It should be remarked that, although this slight collision was immediately due to the mistake of the driver, and to an omission on the part of the guard, it was only a natural result of the objectionable practice of backing loaded passenger trains, which has led to many accidents, and for which I can see no necessity at this station.

Colonel Rich has also reported the result of his inquiry into the circumstances connected with the accident which occurred on the 6th May last, at Llandore station of the Great Western Railway. This slight collision was caused by the three coaches not having been tightly coupled up to the engine before the shunting operation was commenced. The screw coupling, being loose, was no doubt lifted off the hook when the three coaches were pushed by the engine towards the branch line train. The Company have given orders that in future these couplings shall always be screwed up tight before the shunting is commenced; and also that when one of the vehicles to be shunted is a brake-van, a second man shall ride in the brake-van.

Major Marindin has also reported the result of his inquiry into the causes of an accident which occurred on the 14th May last, at Masboro' station, on the Midland Railway. This slight accident was caused by the points of the cross-over road north of the station being pulled over while the train was setting back, so that the centre carriages were turned on to the cross-over road, and were dragged off the rails by the two rear vehicles, which were backing along the down main line. I have no doubt whatever, from the evidence, that the driver of the train did not receive a proper signal to set back, either from the guard or from the signalman in the crossing cabin, and that the accident is due to his want of caution; but, at the same time, it furnishes another instance of the danger arising from the objectionable practice of backing loaded passenger trains, which has led to many accidents, and should be avoided as much as possible. It should be remarked that the guard of the train would have been in a position to avert this accident if the continuous brake had been fitted throughout the whole length of the train, instead of to the first six vehicles only, for, the brake in use being automatic, the guard could, and probably would, have applied it, and so have stopped the train when he perceived that the driver was starting back before receiving a signal, and before the cross-over road points had been set for the train to run on the up main line. I am informed that alterations will shortly be commenced at the north end of this station, and that the cross-over road will then be worked from a new signal-cabin close at hand, but I would recommend that this and all other such cross-over roads which are habitually used for passenger trains to cross from one line to another, should be at once fitted with a signal and proper facing-point appliances.

Major Marindin has also reported the result of his inquiry into the causes of a collision which occurred on the 15th May last, at Barton Station, on the Manchester, Sheffield, and Lincolnshire Railway. This collision was due to the driver of the train not having made sufficient allowance for the number of goods wagons on his train being in excess of the regulated number, and for his engine being light, owing to the coal and water having nearly run out. The guard of the train is, however, more to blame than the driver, for he disobeyed, no doubt with the intention of doing his best to forward the interests of his Company, a positive order which limits the number of goods wagons to be attached to these mixed trains, and took on five empty cattle wagons in excess of the regulated load. He did not tell the driver how many he had taken, but the latter admits that he knew he had more on than eight, although he was not sure how many more. There is some doubt whether or not the vacuum-brake on the passenger carriages failed to act, when it was required to avert the collision. The foreman porter, who was on the platform, states that the blocks were on upon the carriages which passed him, while the driver states that the brake did not act when he tested it about 300 yards from the station, or when he again tried to apply it when at the end of the platform, at which point he found that he was not pulling up as fast as he should have done. He states most positively that the indicator on his vacuum-gauge flew back the moment he shut off his ejector, in precisely the manner that it does when a brake-pipe is disconnected, and, although the collision may have been the cause of the disconnection of the pipe which was found in this condition when the train was examined, I am inclined to believe the statement of the driver, and the more so because he does not advance it as an excuse, being quite aware that, according to the rules, he had no right to depend upon his vacuum-brake for stopping at a terminal station, and stating, as he does, that when he first tried it he had no idea that he would be unable to stop by means of his hand-brake as usual. If the driver's statement be correct, this case furnishes a strong argument in favour of the automatic action of brakes, for the driver

would not have been able to run after the brake-pipe had become disconnected, depending upon a useless machine to stop the train in a case of emergency. The running of mixed trains under any circumstances entails a certain amount of additional risk, and should be avoided as much possible ; but where they are run there should certainly be a brake-van at the rear of the train, both for the safety and the company of the passengers. and the servants of the company should not be allowed to break with impunity the rules limiting the number of wagons. It seems that this is by no means the first time that such a breach of regulations has occurred on this branch, and I can hardly believe that the station-master at Barton can have been ignorant of it.

Colonel Yolland has reported the result of his inquiry into the causes of an accident which occurred on the 19th of May last, at the London Bridge station on the London, Brighton, and South Coast Railway, between a passenger train and a carriage-truck standing close to the buffer-stops at the north end of No. 1 passenger line. In this case, it appears from the evidence, that the 6.20 p.m. up train from Tunbridge Wells to London Bridge reached New Cross at 8.32 p.m., being due there at 8.22 p.m. The train consisted of an engine and tender, four carriages and one brake-van at the rear of the train, in which the guard of the train rode. The train was fitted with the Westinghouse brake throughout, but only had the brake-pipe fitted to the brake-van, without any brake blocks applicable to the wheels of that vehicle. But the brake-van had an ordinary hand-brake in the brake-van, workable by the guard of the train. This train left New Cross station several minutes late, and the signals, according to the guard in the brake-van and the fireman on the engine, were at "all right" for the train to run into No. 1 line at the London Bridge station, as the home or stop-signal exhibited over the elevated girder was down, as well as that at the south end of the platform ; but the distant-signal placed below the platform signal stood at "danger," and showed that No. 1 line, on which the train was to enter the station, had some obstruction on it. This obstruction proved to be a carriage-truck placed close to the buffer-stops at the north end of No. 1 line. A red light was placed on the platform just alongside of the carriage-truck, and this red light was seen by the guard of the train and the fireman on the engine, as the train ran in on No. 1 line alongside of the western side of the platform. The engine-driver states that he did not observe the signal, or number of the line on which he was to travel, placed over the elevated girder, nor the signal placed at the south end of the platform, which were there for the purpose of telling him on which line he was to enter the station, as his attention was attracted to a red light which he thought was placed on the tail of some vehicle standing on the line on which he thought he was entering the station, and which he supposed was No. 2 line. If he had been running on that line, standing as he did, at the left side of the engine, he should have seen the platform but there was no platform to see on that side. The collision was entirely due to his carelessness in not having looked out for and been guided by the two sets of signals, which were placed at the entrance of the station for his guidance, and for having turned on the steam on his engine to go ahead when he was not more than five yards from the carriage-truck in front of his engine. He evidently was not keeping a proper look-out ahead, and the natural inference was that he was not conscious of what he was doing. However, I could not obtain any testimony to prove that he was not sober. No other servant of the Company is to blame for causing this collision.

Major-General Hutchinson has also reported the result of his inquiry into the circumstances connected with the explosion of the fire-box of the engine of a goods train on the 10th February last, near Bury St. Edmunds station, on the Great Eastern Railway. From a careful consideration of the evidence and inspection of the fractured fire-box, there is but little reason to doubt that the explosion was owing to the defective condition of the copper stays in the right side of the fire-box. On reference to Fig. 1, it will be seen that three of these stays, 10, 11. 12, a little below the centre of the box, and near the tube plate, were found to have had old fractures ; and it was at this spot that most probably the mischief first commenced, by the steam pressure here first bulging the copper plate, then stripping it away from the greater part (169) of the rest of the stays, and breaking 14, and then tearing the side plate from the back plate more or less along the angle in which the side and back plates meet. The surfaces of fractures showed very little symptoms of corrosion, certainly nothing to warrant the opinion that the explosion was due to corrosion. There is not the least reason to suppose that there was any excess of steam pressure above that authoriezd, viz., 140 lbs., at which pressure the safety-valves (which had not been, it was stated, in any way meddled with after the explosion) began to ease off when tested in my presence. The explosion occurred, according to the driver's evidence, just as he had shut off steam after drawing 15 wagons out of a siding. The fire-box had been reported as leaking at the stays both on the 8th and 9th February, and on the nights of both the 8th and 9th a boiler smith had attended to these leaks, of which he thought there had been about 20 on each occasion, occurring on both sides of the box in the lower centre portion. About a week before he states that he had expressed his opinion to foreman Gwynn that the stays were getting into a bad condition. Foreman Gwynn, a boiler smith of 30 years' service, had last examined the fire-box on the 3rd February, a week before the explosion, when he had reported its condition as "moderate," meaning, he says, that it would

shortly require a few new stays and tubes. He then found some 20 stays defective, but none of them broken, and did not consider the defects sufficiently serious to render it necessary at once to stop the engine running. He had made a similar report as to the condition of the fire-box in January. It is evident that this foreman, though an experienced man, either did not sufficiently realize the danger arising from the defective condition of the fire-box stays after his examination on the 3rd February, or that he did not then make as careful an examination as he ought to have done. In either case he is directly to blame for the very serious explosion which was so nearly terminating in fatal results.

Major-General Hutchinson has also reported the result of his inquiry into the circumstances connected with the double collision which occurred on the 18th April last on the Cockermouth, Keswick, and Penrith Railway. This double collision, which was nearly being attended by most serious results, though contributed to by other causes, was mainly brought about by a direct violation of the train staff and block telegraph regulations under which the Cockermouth, Keswick, and Penrith single line is worked. The circumstances of the case are briefly as follows:—As the North-Eastern Company's 10.50 a.m. mineral train (a double train consisting of two engines and tenders, 28 loaded coke wagons, and two brake vans), was proceeding on its journey with a train ticket between Braithwaite and Bassenthwaite Lake stations, the rear brake van (owing, it is said, to a somewhat sudden check of the speed preparatory to going slowly through the next station) was detached from the rest of the train about two miles from Bassenthwaite Lake station. The assistant guard of the train, instead of being in his own brake van (the last but one), had without any necessity gone into the rear brake-van, and in consequence the train went forward without any guard, the leading driver picking up the train staff as he passed through Bassenthwaite Lake station, and soon after discovering that he had lost his rear van. Upon seeing this he decided to run on to Embleton (the next station), whence he returned with the staff to Bassenthwaite Lake, sending on his train with the second engine to Cockermouth. On the driver reaching Bassenthwaite Lake a consultation was held with the station-master and the head guard of the mineral train—who came up shortly after the driver—as to what should be done; and on the guard informing the station-master and driver that he had made a positive arrangement with the assistant guard that the van which had been left behind was not to be moved until he (the head guard) returned to it, the station-master gave his consent to the engine proceeding towards the van, though he was aware that the signalman had taken another train on line from Braithwaite, which was then in the section, and would be bringing the train staff. The engine accordingly started with the driver, fireman, guard, and station-master on it, and had proceeded about a mile towards Braithwaite, when, on a curved part of the line running through a wood, steam suddenly appeared through the trees, the speed being about 11 or 12 miles an hour. It is stated that every effort was made to stop the engine, but that it was still in slow forward motion, though in backward gear with steam shut off, when the collision occurred. All the men except the driver had jumped off before this. The driver says that he remained on the footplate, and had just shut off steam and released the engine brake and tender brake when he was knocked off by the collision, the engine thus being left with no one on it. The blow, it is stated, opened the regulator, and before anyone had time to reach the footplate the engine commenced to move back rapidly towards Bassenthwaite Lake, the driver pursuing it as soon as he had recovered himself. The runaway engine passed through Bassenthwaite Lake station at 1.12 p.m. at a speed stated to have been between 40 and 50 miles an hour, the signal-man at first thinking it was on its way back in regular course. He received line clear for it from Embleton ($2\frac{1}{2}$ miles distant) at 1.18 p.m. At about 1.20 p.m. the driver came up in pursuit, shouting to the signalman and porter at Bassenthwaite Lake to telegraph at once to Cockermouth that the engine was running away. The attention of the telegraph clerk at Cockermouth was fortunately obtained at once, and there was just time, upon receipt of the message, to get the passengers out of the 1.25 p.m. train for Maryport, which train was loading at the down platform, when the runaway engine dashed into the rear of the train, completely breaking up the two last carriages, damaging the other two, and detaching the engine and tender (from which the driver and fireman had jumped off) from the rest of the train; the engine and tender were thus started on their way down an incline just beyond Cockermouth station, when they were stopped by a porter, and a third collision thus possibly avoided. To go back to the first collision, it appears that after the arrangement come to between the guards, the assistant guard went back towards Braithwaite to protect the van, met No. 7 down mineral train on its way to Cockermouth, stopped it before it reached the van, and then, after some discussion with the driver, allowed the van to be pushed forward in front of the engine of No. 7 train, notwithstanding the arrangement, which the assistant guard thought himself justified in departing from in consequence of No. 7 train having been allowed to proceed from Braithwaite, and being in possession of the train staff. The speed of No. 7 train was stated to have been about 12 miles an hour when the engine of 6 train was first seen approaching, and to have been reduced to about four miles an hour on collision. The first, though not the most important, cause of these collisions was the improper conduct of the assistant guard of No. 6 train in leaving his van (the last but one), and entering the last van without

proper cause, just before the last van became detached. Had he been in his proper place he would probably have soon been able to attract the driver's attention, when the train could have been stopped and promptly recoupled. The second cause was the disregard on the part of the assistant guard of the distinct arrangement which he acknowledges was entered into between him and the head guard, that the van should not be moved before the head guard returned to it. The third cause was the mistake made at Bassenthwaite Lake station in not positively ascertaining—on its being perceived that No. 6 train had passed with only one van—whether the rear van of this train had or had not been left behind, before permitting a second train to leave Braithwaite without any warning. The fourth and principal cause, however, was the action of the station-master at Bassenthwaite Lake station in permitting the engine of No. 6 train to proceed towards Braithwaite, when he knew that No. 7 train in possession of the train staff had been permitted to leave, and was on its way from Braithwaite. The private arrangement come to between the guards of No. 6 train did not, in my opinion, by any means justify him for breaking both train staff and block telegraph rules. To save the delay of about half an hour he incurred a most serious responsibility, and but for the promptitude which was afterwards displayed by porter Robinson at Bassenthwaite Lake station in first despatching the message about the runaway engine, and then by clerk Patterson at Cockermouth in receiving and acting on it, the loss of life would probably have been great.

Major-General Hutchinson has also reported the result of his inquiry into the circumstances of the collision which occurred on the 18th April last, at Paul's Road junction, near Camden Road station, on the Midland Railway. This collision had its origin in a very unusual cause, viz., in the driver and fireman of the 9.20 a.m. down Metropolitan train having been partially blinded as they started from King's Cross station by a fall of limewash on to the foot-plate of the engine from the floor of a building under construction just above the spot at which the down line enters the King's Cross tunnel. The driver appears, in consequence, to have lost his presence of mind, not to have seen the Paul's Road junction distant-signal at danger, and instead of stopping short of the junction home-signal till he had seen whether or not it was off for his train,—and this, considering the continuous-brake on the whole of the train, and the rising gradient of 1 in 58, he could have done at any moment in certainly less than 100 yards,—he allowed his engine with steam on to approach this signal within 15 or 20 yards at a speed, he states, of between six and seven miles an hour before he was aware that it was at danger, and that then, on shutting off steam and applying the continuous-brake, his engine overran this home-signal by about 37 yards, and there came into collision with the last vehicle of the 7.45 a.m. passenger train from Bedford, the driver of which, on seeing the collision imminent, had tried, by increasing his speed, to avoid by driving clear of the junction. The fireman of the Metropolitan train, though he saw the junction distant-signal at danger, did not draw the driver's attention to it, thinking he would have seen it himself, and he did not see the home-signal before the driver, as steam was damping down on his side of the engine as they were approaching this signal. The front guard was not looking out for the junction-signals, nor did the rear guard observe either of them until he saw the home-signal at danger after the driver had passed it, but when it was too late to do any good with his hand-brake. This collision is, therefore, to be mainly attributed to want of caution on the part of the driver and fireman of the Metropolitan train in approaching Paul's Road junction, though much excuse is to be made for them on the ground of the partial blinding which they had sustained as they started from King's Cross. The guards of the train should certainly have been looking for the junction-signals; had they been doing so, and had they promptly applied their hand-brakes on seeing what was likely to happen, they might have stopped the train clear of the junction-crossing. Much more would they have been enabled to do this, had the continuous-brakes (with which the train was fitted) been of such a nature that the guards could have applied them. It was a very careless act of the contractor erecting the buildings at King's Cross to have allowed mortar to be mixed on an iron plate having holes in it, which holes allowed the limewash to fall on to the railway below.

Major Marindin has also reported the result of his inquiry into the causes of a collision which occurred on the 13th May last on the Midland Railway, at Midland junction King's Cross (Metropolitan). This slight collision was due to a failure in the block working between Paul's Road junction and Midland junction King's Cross, and considering that it took place i na tunnel, and with the atmosphere too thick for the driver of the pilot-engine to see the tail-lamp of the passenger train for above 20 yards, it is fortunate that it had no worse consequence. As usual in such cases, there is a conflict of evidence between the signalmen, the one at Paul's Road junction stating that he signalled forward both the passenger train and the light engine, and received permission to send them on in the usual manner, while the signalman at Midland junction denies having received a signal for any train, after the goods train, which preceded the passenger train, until he received the six-bell signal for the light-engine. Both men are equally positive, both bear good characters, and both have entered up their books correctly; so that it is impossible to determine with certainty which of them is to blame, although, taking into consideration all the evidence,

and the fact that the Metropolitan signalman admits that he had his child in his cabin, contrary to the rules, I am inclined to the belief that the mistake was made in the latter cabin. Wherever the fault may be, it is quite clear that this accident is one of a class which might be altogether avoided by the use of one of the inventions for interlocking the electrical block instruments with the out-of-door signals which have been found satisfactory upon other lines; and it is to be hoped that the Metropolitan Railway Company, and the other Companies interested in these junctions at King's Cross over which the traffic is very great, and where a mistake might lead to a very serious disaster, will consider the advisability of making a trial of the system. The distant-signal which the driver of the passenger train found to be off, although the home-signal was when he arrived at it at "danger," was examined immediately after the accident, and found to be in good order; and it is difficult to account for its having been off unless the signalman in Midland junction had first taken off the signals for this train, and then, finding that the line was not clear into the station, had put them back to "danger" after the passenger train had passed the distant-signal. The manner in which the booking of trains is carried out in the Metropolitan Railway does not give much assistance to the task of finding out where a mistake has occurred, for all that is entered is the time at which the train is due and the time at which it arrives and departs, no record being kept of the time at which the train is given "on line," or of the time at which "line clear" is given, so that the record in one box cannot be accurately checked by that in the next. It is also apparently the practice to enter beforehand the description of the trains and the time at which they are due in consecutive order, which is not at all unlikely to lead to mistakes in the booking when trains are running out of their proper time. I do not consider that the driver of the pilot-engine is much to blame, for he seems to have been running cautiously prepared to stop at the home-signal, and he had no doubt very short warning of the obstruction.

NOTES.

The Railway Review describes a new and novel railroad velocipede or hand-car, which from its lightness, simplicity and cheapness, together with the great speed which may be attained with it, must commend itself to railroad men. The light but strong frame-work is supported by four wheels, termed suspension or wire spoke wheels. The forward wheels are the drivers, and, being very high, enable it to run very fast at comparatively slow revolutions of the crank. There being no gearing about it and but few movable parts, there is scarcely any friction, and it requires only a pressure of three pounds to start it in motion. The driving wheels revolve independently of each other on the short, seperate shafts or axles, so arranged that they do not extend across the car, thus leaving room for the operator, who sits low midway between the two driving wheels, which he revolves by two hand cranks. This important arrangement of the driving wheels enables the car to run as easily on curves as on a straight line, and gives the operator means of resting himself by changing the motion of his arms, hands, and body—it being an easy matter to turn the cranks either in line or alternately, There is another form of this device in which the driving wheels are operated by the feet, or by both hands and feet. A novel and useful feature of the machine is in an extra detachable seat for an additional passenger. In connection with the seat are two upright handles or levers, with connecting rods leading to the cranks of the driving wheels, by means of which the occupant of the extra seat may assist in propelling the car. The larger machines will be provided with rows of seats, and levers are so extended that from two to ten men or more may assist in propelling the car, and thereby attain a great rate of speed with but comparatively little exertion from each man. A car, said to weigh about 100 lbs., will attain a speed of 20 miles per hour. It can be stopped almost instantly and easily taken from the track by one man. By an additional weight of about 25 lbs. to the man the capacity may be increased up to 20 men; and such a car may be taken off the track by four men, out of the way of passing trains. These cars must be a great convenience to a party of engineers who have work to do out on the line of the road or for bridge inspectors, track examiners, road-masters, fence builders, station-house builders, section gangs. Arrangements are being made by the inventor to manufacture these cars of five different sizes to supply the demand. Further information may be had by applying to the inventor and manufacturer, Mr. H. T. Stock, of Toledo, Ohio. One of these cars is now in use on the western division of the Lake Shore and Michigan Sourhern road, by Mr. T. F. Whittelsey, roadmaster, at Englewood, Illinois.

The New Narrow Gauge Rolling Stock for the Wynberg Line.—On May 17th last, at midday, the first narrow gauge train, fitted with the latest appliances, was

run between Cape Town and Wynberg, under the supervision of the Commissioner of Public Works and the General Manager of Railways. The train was under the charge of Mr. Thornton, Chief Locomotive Superintendent of the Colony, and Mr. Stevens, Locomotive Superintendent for the Western System, Mr. O'Neall Neall, Assistant Locomotive Superintendent, Mr. J. Brown, the Maintenance Engineer, and Mr. Richardson, of the Traffic Department. Several Members of Parliament were also present, and the trial was in every respect a satisfactory one. Mr. Thornton himself drove the train. The result of the trial showed that the vacuum brake works with greater regularity and and smoothness, and stops the train in a shorter distance, than the chain brake. All the disadvantages we have experienced in the Cape Colony respecting the chain brake were experienced on the London and North-Western Railway, which, after spending large sums of money in endeavouring to improve the chain brake, have now abandoned it for the identical brake now fitted to the new Wynberg rolling stock. The great object of brake inventors has been to combine efficiency and certainty of action with simplicity. And this appears to have been attained by the simple vacuum brake, for although there are no valves throughout the whole train, both driver and guard are warned if there is anything out of order. The brake is under the control of the driver of the engine. Under each bogie carriage are two sacks or cylinders from which there is an open pipe connected with an injection pipe on the engine. To apply the brake the driver simply opens a valve to allow the steam to pass through the ejector, which causes a vacuum in the pipe, which pipe runs through the whole length of the train. This pipe has branches to the actuating cylinders, two of which are placed under each carriage, which are connected with brake blocks on the wheels. In the event of a pipe breaking or leaking there is placed on the engine foot plate a tell-tale gauge, which denotes to the driver whether the brake is in working order or not. In the event of the vacuum brake getting out of order, the engine-driver has at his command his steam brake, which can be applied to the engine wheels, also a hand-brake, which can be worked by the driver on the engine or by the guard in the brake-van. The train consisted of eight long bogie carriages capable of seating 400 persons, and three goods wagons were also attached to it, to show the applicability of the vacuum brake to both passenger and goods traffic. Leaving Cape Town at 12.20 the train arrived at Wynberg shortly before one o'clock, after having made stoppages at every station. As an instance of the efficiency of the brake we may mention that the train ran down the incline from Mowbray to Roseband at the rate of 32 miles an hour, and stopped at the Rosebank station in thirteen seconds after the application of the brake. On the return journey a stoppage was made at Claremont, which is also at the foot of an incline, and the rails were slippery from a drizzling rain, in seventeen seconds, the train having been stopped when travelling at the rate of thirty-nine miles an hour. Regarding the rolling stock, the carriages are as roomy and as comfortable as can be designed for a narrow gauge railway, and they were built by the same makers as those who supplied the carriages to the Wynberg Railway Company. The length of each carriage is forty-one feet, which is rather more than the carriages on the Metropolitan Railway in London, and is about equal to the length of those bogie carriages which are now being introduced on the main lines in England.

The Taff Vale at Cardiff.—A new station of the Taff Vale Railway Company at Cardiff has been completed and passed by the Board of Trade inspector, Colonel Rich, and on Monday it was opened for traffic. The new structure is on the down line, opposite the old station, and comprises a block of offices, a long circular and covered platform, and there is also a subway communicating with the up-line station. The whole of the work has a massive appearance, and has been carried out under the superintendence of Mr. H. O. Fisher, in a creditable manner by the contractor, Mr. R. Price. There is a separate approach road, and a footway, from Crockherbton, near the Rhymney Railway Bridge, and the new station will be found generally to be a great convenience to the public.

New Zealand Exhibition.—The Phosphor Bronze Company, Limited, have been awarded the Gold Medal for their fine collection of phosphor bronze specimens at the New Zealand Exhibition.

During February of this year, the importation of pig iron into Austria reached 5,185 tons against 1,863 in February, 1881. This increase is due to merchants and manufacturers have availed themselves of the opportunity of securing a stock before the introduction of the new customs tariff.

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LONG SPAN BRIDGES AND VIADUCTS, IN IRON, STONE, BRICK, AND TIMBER.

(*Continued from page* 173.)

WE can now proceed to consider the practical design and construction of iron viaducts, of the types referred to in the foregoing remarks.

In the first place must be considered the nature of the foundation upon which the work is proposed to be built; if the ground is of a tenacious character and uniform composition, free from boulders, such, for instance, as a strong blue or grey clay, then screw piles will be suitable. One great advantage of screw piles is that their use saves excavation, but on the other hand they afford a very small bearing surface in comparison with masonry foundations, so that if the ground is bad the iron piers must be carried on masonry beds of sufficient thickness to distribute the superincumbent loads over their entire areas uniformly, and when this construction is adopted, the base castings of the columns are to be fastened by holding down bolts passing completely through the masonry and anchored to plates beneath. Some space must be allowed round each bolt in carrying up the masonry in order to allow of its top being adjusted properly to the holes in the base castings of the columns; this done, the spaces around the bolts may be filled in with cement or melted sulphur, the latter preferably. If the masonry covers a considerable area, and the piles are some distance apart, it will be advisable to use, instead of anchor plates, *H* iron bars, extending across the foundations, so as to receive the bolts from the column bases on both sides, thus getting a better hold upon the masonry, and virtually giving it more solidity. The *H* irons before being used should be heated and dipped in boiled oil, in order the better to enable them to resist oxidizing influences. The working strength of the holding down bolts and their connections, must, of course, be equal to the weight of the foundations through which they pass, in order to secure the unity of such foundations with the superincumbent parts of the pier, so that in fact it cannot upset without pulling up the masonry or brickwork to which it is anchored, and this rule is also to be adopted for the bolts connecting the upper tiers of columns with each other. Now it is evident that if the pier be actually tipped in one or other direction, each set of bolts will have its own share of the masonry to sustain.

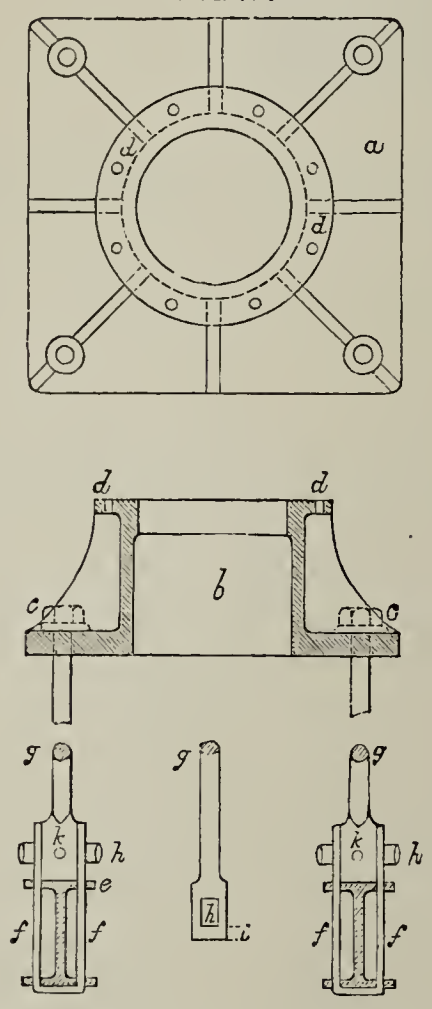
For example, assume a pier to consist of eight columns in two rows under the rails raking out to a width of 24 ft. at the base of the outside columns, the total width of masonry being 30 ft., and the inside piles raked so as to divide the width of the foundation evenly, then at the bottom the distance of the columns will be 10 ft. apart from centre to centre *across* the line of the viaduct, and the distance in direction of the length we will take as 6 ft., the total breadth in this direction of the masonry being 12 ft. Then the maximum weight will be carried by one of the inner columns, sustaining an area of $10 \times 6 = 60$ square ft., which, if the foundation be 7 ft. thick, and of stone will weigh $60 \times 7 \times 120 = 50{,}400$ lbs. $= 22.5$ tons. There are four bolts, hence each will require to have, at 5 tons safe working load per sectional square inch, an area of $\frac{22.5}{4 \times 5} = 1{\cdot}125$ square inches *at the bottom of the thread.* The bolts must, therefore, be $1\frac{5}{8}$ inch diameter, deducting the depth of thread $\frac{1}{5}$ inch, the diameter remaining corresponds to a sectional area of 1.178 square inches. Of course we use Whitworth's pattern of screw. The nuts must be, at least, equal in height to the diameter of the bolt, and the threads must be properly cut, as when the nuts are once tightened down they will not have again to be removed, they may be secured by burring down the ends of the bolts.

a Fig. 1, is a plan of the base casting of the piers, *b* a vertical section of the same, *cc*, are the nuts on the holding down bolts, and *dd* holes for the bolts connecting the columns with the base castings. The lower ends of the bolts are shown at *gg*, where they are secured by cotters *hh*, to straps *ff*, *ff*, which embrace the webs of the *H* irons *ee*, as shown, slots being cut in the flanges of the *H* irons to allow the sides of the straps to pass through.

These straps must have an area equal to that of the bolts, hence if they are made $1\frac{1}{2}$ inch wide, the thickness of each side must be $\frac{1.178}{2 \times 1.5} = 0\ 392$ inch, say $\frac{1}{2}$ inch, which will also be right for the bottom of the stirrup, which must be made with square corners to bear fairly against the underside of the *H*

iron. Extra width, however, must be allowed at the top for the loss by the cotter holes. The cotter *h* will be in double shear, hence its section may be the same as the general section of the strap *ff*, that is, $1\frac{1}{2}$, inches by $\frac{1}{2}$ inch thick, this will

FIG. 1.



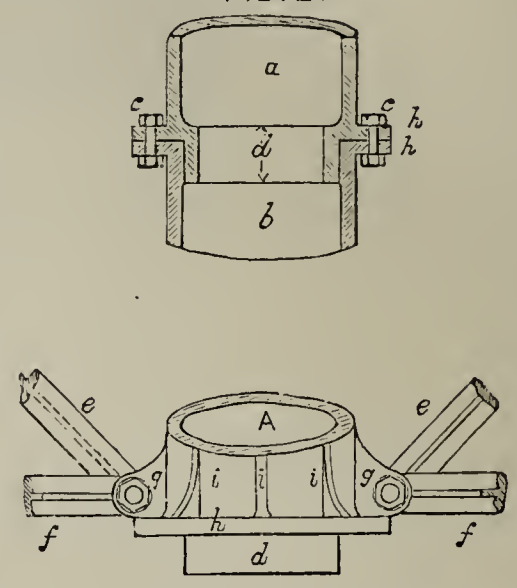
require the strap to be 2 inches wide at the top, and as a matter of practice it may be as well to keep it of the same width throughout. The lower end *g* of the rod is to be widened out and thickened to receive a cotter hole, the thickness *i* must be sufficient to give a shearing area equal to that of the cotter, therefore if it is two inches wide it must be at least $\frac{3}{8}$ inch thick; but in positions such as this, where the work cannot be got at to see if it bears properly, or is generally in good condition, it is better to have an excess of strength, hence we should make this thickness, and also that of the eyes-ends of the straps measured in the same direction $\frac{3}{4}$ inch. The cotters *hh* should have only a very slight taper, and when driven home should be secured from slipping by steel pins *kk*.

The foundations having been decided upon, the detailing of the columns must be dealt with, the question then arises, are they to be cast or wrought iron? We will take cast iron first.

Having ascertained the necessary thickness of the columns, the method of jointing them and the connections for the bracing bars must be carefully considered. The connection of the columns one with another should be absolutely rigid to ensure the unity of the pier, and this can only be ensured by using a proper mode of construction, clearly shown on the drawings *and firmly insisted on* in the works.

There must be no possibility of the columns shifting laterally, one upon another, and therefore a spigot joint should be used as shown in vertical section at *a*, *b*, Fig. 2. The faces of the flanges are to be turned so as to fit truly and the spigot *d*, is to be turned to gauge, to fit the truly bored upper end of the column *b*. This spigot does not need to be more than 2 to

FIG. 2.



$2\frac{1}{2}$ in. long, as if the flanges are properly secured there can be no longitudinal movement. The holes for the bolts *c*, *c*, should be accurately drilled to template to receive the bolts, which are to be *turned and chased*, that they may fit properly in their places and all be interchangable, this will save a lot of trouble in erection.

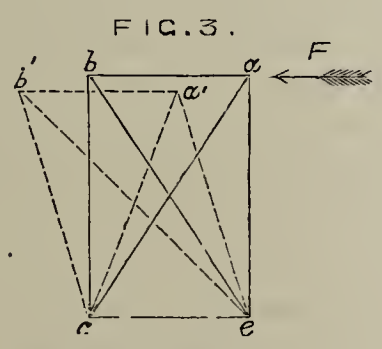
We feel we cannot lay too much stress on the necessity of examining the work during manufacture, not that we have any intention of discrediting contractors as a body, but there are undoubtedly among them firms who commit errors even if they be errors of omission arising from laxity in the supervision of their subordinates, and it must be acknowledged, however much it may be the fashion to gloss such things over, that some manufacturers deliberately send out defective work, freely cloaking their faults with *beau monteague*. By the way, it is curious that this term, known for years in "the trade" was a shibboleth to the outside public until the notorious failure of the Tay Bridge caused its meaning to be brought to light. There is of course only one safeguard, that is, constant and conscientious inspection of the work.

The flanges *h*, *h*, should be made a little thicker than the shaft of the columns, thus if the shaft is $1\frac{1}{8}$ inch metal, the flange should *finish* to $1\frac{1}{4}$ inch thick. *A* is an elevation of the lower part of a column, showing the lugs *g*, *g*, for the attachment of the bracing bars *e*, *e*, and *f*, *f*. These lugs must be very carefully proportioned, for they really form exceedingly critical parts of the structure, and it would certainly be preferable could they be altogether avoided, without introducing anything else equally objectionable. These lugs have a tendency to crack off the castings in cooling, and then an attempt will be made to "burn on" new ones; but this is a very untrustworthy method, and we should distinctly forbid any such tinkering. Moreover, where (in the absence of responsible overlookers) this burning on is had recourse to, it is too often very improperly performed. The casting is taken without preparation and the new part burnt on to it, instead of first

cutting away the metal for some little space around the fracture, so that the new part may have sound unstrained metal to burn on to; properly carried out, this may be permitted in unimportant parts of a structure which are not subject to tensile strains, but wherever tensile strains can be brought into action it must not be allowed.

The lugs will be cast on in pairs, the bracing bars being placed between them, and there secured by bolts. The webs of the tee irons must be cut away where they pass between the lugs, and at that place the tables must be thickened to make up for loss by bolt-holes, and also to give a better bearing on the bolt. Let us now examine the strains on the diagonal bracing bars under wind pressure, assuming as in our former example a pressure on the superstructure = 2,500 sq. ft. × 50 lbs. = 125,000 lbs. acting horizontally to distort the bracing, if there are eight columns in the two rows under the rails, there will be twelve diagonal bracing bars to resist this force. We cannot regard the diagonals to the end raking piles as affording equal assistance, and shall here neglect them. The proportion of force for each diagonal will be $\frac{125,000}{12} = 10,417$ lbs., the strains produced by which may be determined by the parallelogram of forces thus:—Let the wind force act in the direction *F*. Fig. 3, upon the bracing bars, *ab*, *ac*, and columns *ae*, *bc*. The tendency will be to push over the columns, *ae*, *bc*, towards the positions shown by a^1 *e* and b^1 *c*, until the resistance along *ba* is equal to the wind pressure. There will then be tensile strain on *ab* and *ae*, and compression on *ac*, and the parallelogram *abce* will give the relative forces. Let *ab* = 54 in. and *ac* = 108 in., then the force upon *ac* will be 10,417 lbs. × $\frac{ac}{ba}$. *ac*, however, =

FIG. 3.



$$\sqrt{\overline{ba}^2 + \overline{bc}}, \text{ and } bc = ae$$

therefore,

$$ac = \sqrt{54^2 + 108^2} = 120.74 \text{ inches};$$

the strain therefore upon the bar

$$a\,c = 10,417 \text{ lbs.} \times \frac{120,74}{54} = 23,292 \text{ lbs.} = 10.4 \text{ tons.}$$

Allowing 3 tons per sectional sq. in. as safe working load, the sectional area at the middle of the bar acting as a strut to resist flexure must be

$$\frac{10.4}{\cdot 3} = 3.5 \text{ sq. in., nearly};$$

between the lugs the area to resist simple compression must be

$$\frac{10.4}{4} = 2.6 \text{ sq. in.}$$

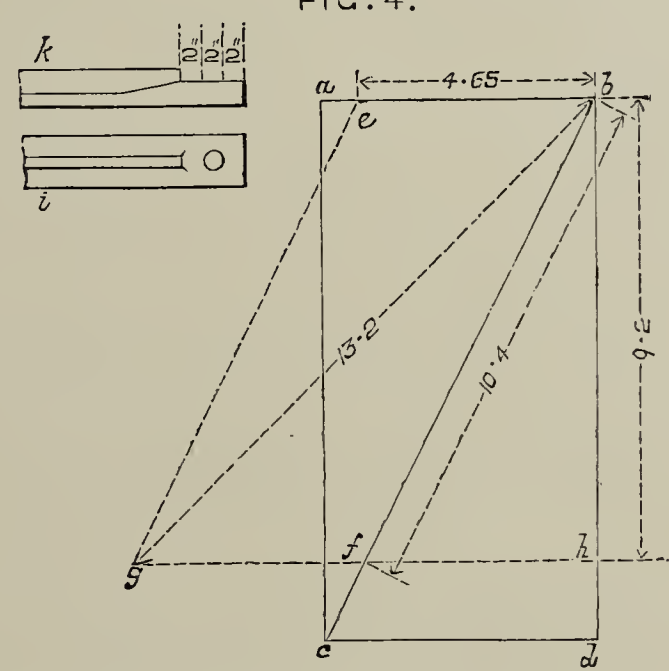
and these areas will of course cover all that is required, when by opposite stress the bar is thrown into tension. If the two diagonal bars act *exactly equally*, the share of strain passing to *be* will produce compression on *ab*; this, however, will only equal 10,417 lbs., but it is usual to keep these bars of the same section with the diagonals *a c*, *b e*.

The size of tee iron required will be 4 in. × 3 in. × $\frac{1}{2}$ in. if the tee irons are rolled full, so as to give the full sectional area of 3.5 sq. in. If there is any doubt about this, they should be figured 4″ × 3″ × $11\frac{2}{3}$ lbs. per lineal foot, $11\frac{2}{3}$ lbs. being the weight corresponding to the required section, as one square inch weighs $3\frac{1}{3}$ lbs. per lineal foot.

We must now determine the strain on, and proportions of, the bolts and lugs, from the strains on *a b* and *a c*; which are 4.65 tons and 10.4 tons respectively. From these strains must be found the resultant strain on the bolt and lugs.

Fig. 4 is a diagram of the centre lines of the bracing, drawn one fiftieth full size. To a scale of five tons per inch mark off 4.65 tons from *b* along *b a*, and 10.4 tons from *b* along *b c*, and from the points *e* and *f* so determined, draw *e g* parallel to *b c* and *f g* parallel to *b a*, both meeting in *g*, then the

FIG. 4.



diagonal *g b*, which scales 13.2 tons will be the strain upon the bolt at *b*, and this strain may act in either direction, so as to produce either tension or compression on the lugs. The bolt itself will be in shearing strain on two areas, one on each side of the bracing bars, hence each area will sustain a strain of 6.1 tons, andtherefore require to contain

$$\frac{6\cdot 1}{5} = 1\cdot 22 \text{ sq. in.};$$

corresponding to a diameter of nearly $1\frac{1}{4}$ in., which has an area of 1.227 sq. in. This $1\frac{1}{4}$ hole will reduce the effective width of the bar to 2.75 in. The area, however requisite to sustain the compression, has been shown above to be 2.6 sq. in., hence the diameter of the bolt multiplied by the thickness of the bar between the lugs must be made equal to this, as that corresponds to the sectional area of bar actually bearing upon the bolt. This, therefore, would require a bolt two in. in diameter, the end of the diagonal bracing-bar being thickened to 1.3—say $1\frac{3}{8}$ in. between the lugs. The area required to resist tensile strain, on the sides of the bolt-hole will be

$$\frac{10.4}{5} = 2.08 \text{ sq. in.}$$

There will then be ample, as the area left is equal to $2 \times 1.375 = 2.75$ sq. in. The margin at the end of the bar should also be two 2 in. long, so as to give an area equal to the sum of the nett areas on the centre line of the bolt hole. The end of the bar is shown in plan and elevation at *k* and *i*. Fig. 4. The horizontal bar will not require so much thickness as the diagonal, the area necessary for compression being

$$\frac{4.65}{4} = 1.162 \text{ sq. in.,}$$

corresponding to a thickness of $\frac{1.162}{2} = 0.581$, or say $\frac{5}{8}$ of an inch. The distance between the lugs, allowing 1-16th inch for clearance will therefore be, $1\frac{3}{8} \times \frac{5}{8} \times$ 1-16th = 2 1-16th in.

The lugs must be calculated for tensile strain, under which they yield the least resistance, then there will be ample strength to resist the compressive strains. The safe tensile strain on the cast iron will be taken at 1.5 tons per sectional sq. in., there will then be required a sectional area in each lug of

$$\frac{13.2}{2 \times 1.5} = 4.4 \text{ sq. in., that is } 2.2 \text{ sq. in. on each side of}$$

the bolt hole, so that if they be cast $1\frac{1}{8}$ in. thick, their radius must no where be less than 3 in. The strengthening brackets, *i*, *i*, *i*, Fig. 2, should also be cast $1\frac{1}{8}$ in. thick, the same as the shaft has been assumed.

There remain now for consideration the bolts connecting the flanges of the columns, these must be designed to resist the tensile strain put by the wind pressure on the column at *bd* Fig. 4. Draw *fh* parallel to *eb* then *bh* which scales 9.2 tons is the force to be dealt with, but this is quite insignificant, and practically we should not put in less than eight bolts 1 in. in diameter, and in fact as we get lower down the pier the overturning moment has to be considered in its effect on the bolts. In treating the holding down bolts we found it necessary for the unity of the pier that for each column there should be four bolts, giving together a nett area of at least 4.5 square in., if in the next joint, that of the base casting with the bottom tier of columns, there are eight bolts, each must have 0.56 square inches area at the bottom of the thread corresponding to a diameter of 0.84 in. at that place, adding the depth of the thread we get the diameter $1\frac{1}{4}$ in., and regarding the pier as being in strength the same as if made of one solid piece, this strength would have to be increased as we rise, to take the additional weight of the columns.

The columns and their appendages having been in this case disposed of, it becomes necessary to make some remarks on their manufacture.

In the first place it is highly important that the columns be cast in an upright position, as otherwise it is impossible to obtain absolutely satisfactory results. If a column is cast on its side the metal is not run under the same pressure throughout, therefore it will be denser on that side which is lowest in the mould, and in addition there is a tendency to float up the core, so that there will be least metal at the upper side where most is wanted, for its density will be less there than elsewhere, and moreover there will, at that part, be a tendency to other faults such as honey combing from the accumulation of air which has not sufficient egress, also the accumulation of scale floating to the highest part of the mould.

If on the other hand the column be cast properly in a vertical position there can be no tendency in the core to move to one side or the other as the metal will press equally all round, and therefore the column will be of uniform thickness, and the gases and scale will readily ascend to the head, and so leave the shaft of the column sound and homogeneous. There is only the first outlay in forming a proper pit in which to cast the columns in foundries where such work is taken, and this ought to be repaid by the saving in "wasters," and also by the increased amount of business secured by a character for good work, for it is certain that engineers will give the preference to those foundries where the work is vertically cast, if they act in a disinterested spirit. Thinner metal may also be used where we are sure that it *will be* uniform all round the column.

It has sometimes been asserted that it is difficult to determine the variation of thickness without drilling holes in the columns, but this is not the case, for a simple system of testing will settle the point of uniformity. Place the column to be examined on its side, and test its deflection under one quarter its calculated breaking load, then turn it a quarter round, and again test it, and similarly through the other two quarters. If the casting is of uniform thickness and homogeneous the four deflections will be sensibly equal, but otherwise they will differ. It is also advisable if a very great number of columns are being supplied to take one or two of the worst looking and test them to breaking strain, in order to ascertain the quality of the iron, instead of relying solely upon the results of experiments on special test bars, for besides other matters being often favourable to the better casting of these bars, *we have heard of special days being appointed for the casting of test bars.*

It may not be out of place here to refer to the effects of some kinds of water upon cast iron. It has been found that in certain localities all the metallic or ferruginous portion of cast iron piles has been gradually dissolved away, leaving only the graphitic and silicious skeleton of the work exhibiting the form, but lacking the stability required. It may readily be imagined that columns or piles standing in streams or by washes, through which flows the refuse from factories employing chemical processes may be rapidly deteriorated, and sometimes stagnant or brackish water will have similar effects.

If then it is proposed to use cast iron piers in water of an unknown quality the precaution should be taken of first immersing for a considerable period sample bars of cast iron with different protective coatings, and some merely in their sand skins before putting down the foundations, and there will usually be ample time for these experiments during the

arrangement of preliminaries to the commencement of the work, but there should be no delay in commencing, so as to carry the test through the year.

In some sandy bottoms of estuaries a peculiar kind of pile known as the disc pile has been successfully used; we believe it was originally proposed by Mr. Galloway, and subsequently adopted by Mr. Brunlees. It consists simply of a pipe with a disc at the bottom, the disc having feathers or ribs cast on it of which the use will presently appear. The disc is perforated in the centre to allow the end of a pipe to be temporarily passed through it; the mode of sinking is as follows,—the pile being placed *in situ* with a head stock on it, and a pipe about two inches in diameter passed through the hole in the disc and connected at its land end with a pump, the pile is partially rotated right and left alternately so that the ribs on the disc loosen the sand, which is then blown out from under the pile by a jet of water forced through the pipe to the underside of the disc, when the pile has sunk low enough, it is solidly set down by a few blows from a monkey, and the columns upon the piles having been properly braced together should be bottom ballasted with heavy shingle, which will also have the effect of steadying the sand bottom and hindering it from moving with the tide.

In some lofty viaducts, instead of grouping small cast iron columns together to form a pier, two large cast iron cylinders filled up with concrete or brickwork or a combination of the two have been adopted; it is interesting to enquire into the relative cost of the two systems.

A pier of ten columns, each 18 in. diameter, 200 ft. high was estimated (page 168) to cost £2,268 for cast iron. If we assume two cylinders 210 ft. long, 6 ft. diameter, and 1¼ in. thick in rings, 5 ft. high, and each ring in four segments with 3 in, flanges for joints, the cost for cast iron upon the same data will be £1776. In the former case, the wrought iron bracing was estimated at £784. For the cylinders the bracing will be 14 tons at £16 = £224. So far then the cylinders show a saving in metal work of, £3,052 – £2,000 = £1,052; the question is, whether this will cover the cost of concrete. In the two cylinders there will be a total of 400 cubic yards. In such a position we may take 20s. per cubic yard as a price corresponding to the others, this will give for concrete £400, making a total of £2,400 for the cylinder pier against £3,052 for the grouped columns. Next as to stability. The weight of cast iron in one column is 99 tons nearly, and adding 5 per cent. for bolt heads makes it up to 104 tons nearly. The weight of concrete, which as it will have to carry the load must be of good quality, should be about 135 lbs. per cubic ft., then in one cylinder there will be 5,400 cubic ft. × 135 lbs. = 729,000 lbs. = 325 tons, in all making a weight of 329 tons, without bracing. The total weight of the two cylinders and bracing will therefore be 672 tons and the moment of lateral resistance to overturning will be 672 tons × 11 ft. = 7392 ft. tons. The stability of the pier formed of grouped columns is 301 tons × 23 ft. = 6923 ft. tons; showing a slight advantage on the side of the cylinder piers.

Although formerly cast iron could be relied upon, yet it must be admitted that for constructional purposes engineers have had good reason in recent years, to regard that material with great suspicion for improved (?) methods of manufacture, allow such inferior stuff to be cast into shape, that we do not know what quality we get nor how far it may be relied upon, hence the almost universal adoption of wrought iron where it can be applied, and even its introduction in the place of cast iron for columns.

The only wrought iron piers with which we are acquainted in England are those carrying the Halesowen Viaduct, the centre pier being about 100 ft. high. Each pier consists of four large *H* irons having a suitable rake, and braced together by horizontal *H* irons and diagonal tie rods. There are however two objections to this mode of construction; one that the joints of the bracing bars with the main *H* irons are very awkward to make; and the other, that *H* irons of large section are very liable to be weak in the root; this is apt to occur in good tough iron, even to the extent of showing cracks in the bars, hence deep *H* irons must be rolled of very soft and generally inferior iron. The greater quantity of *H* iron is rolled in Belgium.

There is, however, a method of building up wrought iron columns which, although it has been known in England for the last twenty years, does not appear to have attracted the favourable notice of English engineers for English work, although it has been used with highly satisfactory results abroad and in the colonies.

The first step to induce its adoption, is to modify the deeply rooted conviction that cast iron on account or its superior resistance to compression is *the material* for columns. There is no denying the truth of this, could we always be sure of the quality of the material, but it is the unreliability of cast iron, together with its tendency to snap, that inclines us to reject it as a material for use in structures of considerable magnitude. Even if wrought iron is weak it will give some indication of approaching failure in cases where cast iron will give way at once and without any notice.

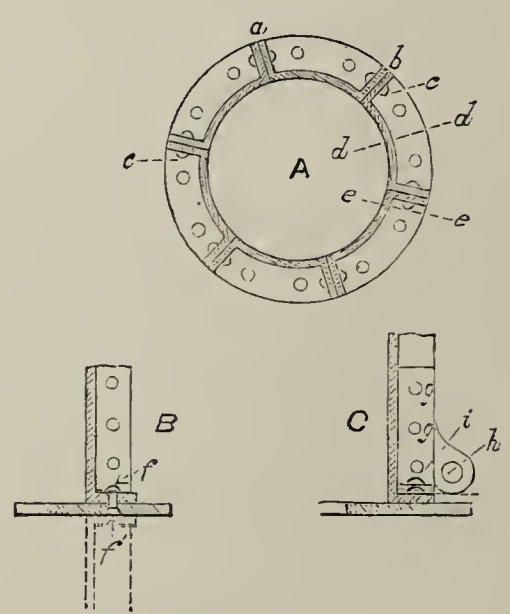
Fig. 5 *A* is a horizontal section of a wrought iron column built up of channel irons *ab* rivetted together by rivets *c,c*, the ribs formed at the points *a* and *b* very greatly assist in stiffening the column laterally, and we are sure of having uniform strength on each side of the column, and it is also no trifling advantage that it is far more suited to resist blows than cast iron. We have now to compare direct strength and expense.

We will assume the piers to be so braced that the length is ten times the diameter, this in the wrought iron columns being measured over the joint ribs. Then the breaking strengths per sectional square inch will be, taking Gordon's rules for channel iron as applicable to the section *A*—

Cast iron $\frac{36}{1 + \frac{10^2}{400}} = 28{\cdot}8$ tons. Wrought iron $\frac{19}{1 + \frac{10^2}{900}} = 17.1$ tons.

There is, however, reason to believe that the strength of the section *A* will be much greater than this. but we have not any reliable experiments to certainly settle the matter. We should, however, be justified in taking four tons per sectional square inch, as safe working strain throughout, and for the cast iron we do not think it safe to take a less factor of safety than 6, giving for working strain 4.8 tons per sectional square inch. As the ratio of length to diameter increases the comparison becomes more favourable to the wrought iron column. Thus, if the length is twenty diameters the breaking weights will be cast iron eighteen tons per sectional square inch, and wrought iron 13.2 tons, giving for working strains three tons in both cases.

FIG. 5.



The opinion of the Broad of Trade Authorities on the relative values of cast and wrought iron is clearly shown in clauses 17 and 18 of their "Memorandum of Important Requirements." "17. In a cast iron bridge the breaking weight of the girders should be not less than three times the permanent load due to the weight of the superstructure, added to six times the greatest moving load that can be brought upon it."

"18. In a wrought iron bridge the greatest load which can be brought upon it, added to the weight of the superstructure, should not produce a greater strain on any part of the material than five tons per square inch."

We do not, as a rule, find any girder iron of ultimate strength exceeding 21 tons per square inch, hence the factor of safety adopted for wrought iron is practically 4·2, while that for cast runs as high as six, where the strain is accompanied by vibration.

It is a practical difficulty that there cannot exist any *applicable theory* of the strength of columns unless perfectly uniform material is found, for the columns actually yield by bending, which would not occur unless one part of the section offering less resistance than another permitted the metal to compress more at that part, and so cause the work to deviate from a straight line, but the nearer we approach uniformity of material the less influence will the ratio of length to diameter exert over the ultimate strength, and that is the reason why, with increasing proportional lengths, the working strength of the wrought iron column overtakes that of the cast. Of course were the material absolutely homogeneous, the resistance would be the absolute ultimate resistance to crushing.

The question of the determination of factors of safety is not nearly so simple as might appear to the superficial observer, and it is a point the discussion of which is, we fear, approached with too much nervousness by some who should be competent to give decisive opinions. If we accept the dictum that the elastic extensions and compressions are, within the limits of elasticity, directly proportioned to the strains, it is not from the values of the ultimate strengths that the working stresses must be determined, but from the limits of elastic resistance. Here we are met with the fact that some slight "permanent set" is noticed on first applying even very slight loads, but we think it may be shown that this is not true permanent set, regarded in the light of permanent injurious distortion or incipient rupture of the texture of the material, but rather an accommodation to one another of atoms previously so crowded together as not to lie in the best relative disposition for the exertion of their maximum cohesive attractions. If the first permanent set or disarrangement of atoms indicated the giving way of certain fibres, so to speak, the total fracture would evidently occur without any additional load being applied, as the material would continue to yield in detail, but it is found that after a certain amount of permanent alteration has occurred, much greater loads may be applied without causing any *further permanent set* until the true limits of elasticity are reached, when all the atoms acting to their best advantage, may not be further separated without passing beyond the spheres of their elastic cohesion.

The limit of elasticity for cast iron is given as 15,300 lbs. per sectional sq. in., that for wrought at 17,800 lbs. per sq. in., hence so far as these facts are concerned, we shall approach the point of incipient permanent injury sooner in cast than in wrought iron, and when once the work of destruction is commenced it must go on.

Weight for weight the wrought iron is, of course, more expensive of the two, but it very commonly happens, that castings must practically be made thicker than is absolutely necessary for strength, whereas we can keep wrought iron scantlings practically very close to the actual requirements of the work; but these, however, are points that cannot be settled on a general basis, as they will be specially influenced by the conditions of each individual case.

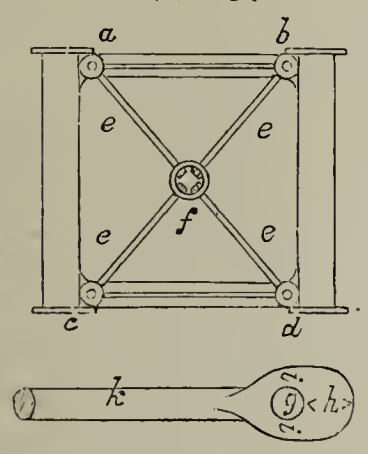
There is an objection to the combination of cast and wrought iron as existing in a pier formed of cast iron columns with wrought iron bracing, arising from the unequal expansion and contraction of the two metals under variations of temperature in the ratios of 71 for wrought to 63 for cast iron. In Eng-

land the variation of temperature is about 80° Fahr., corresponding for wrought iron to a difference in length of $\frac{1}{1800}$ and for cast iron $\frac{1}{2030}$; in a length of ten feet the actual difference would be less than 0·008 inch, hence this objection has no practical foundation, although it has at various times been much talked about. Having, however, satisfied ourselves by this calculation, the matter may be dismissed finally.

The next consideration in connection with the wrought iron columns is the attachments. In some existing structures, the caps and bases have been made of cast iron, in order to afford convenient means for connecting the ties, but in so doing the objectionable cast iron lugs must be re-introduced, but this may be avoided by pursuing the mode shown at Fig 5. At *B* is shown a vertical section on line *d d;* at the bottom of each channel iron the two side webs are cut away, and the central portion bent up at right angles as shown, and firmly secured to a stout wrought iron ring to form a flange, or, if desired, the rivets *f*, instead of being countersunk may, where a joint is required, be carried right through to connect with the column in the tier below, as shown by the dotted lines at f^1. The horizontal and diagonal bracing is carried by wrought iron lugs, as shown at *C*, a vertical section on *e e*. They are two wrought iron brackets connected with the vertical rib by the rivets *g*, *g*, and the flange by rivets *i; h* is the hole to receive the bolt by which the bracing bars are held. By this arrangement, a very reliable pair of lugs is formed, much lighter and neater than those necessary on cast iron columns.

In the examples referred to, the bracing bars have been assumed as tee irons capable of acting as ties or struts, in another system now to be described ties alone are used for the diagonal bracing, stiff sections being retained for the horizontal bracing.

FIG. 6.



In Fig. 6, *a,b,c,d*, show the four pairs of lugs belonging to one bay of bracing. *e,e,e,e*, are the bracing bars made with eyes at one end, and being screwed at the other, the screwed ends must be made of larger bars than the general run of the tie, so as to have at the *bottom of the thread* an equal diameter with the latter. In the centre of the bay the tie rods pass into a strong ring, and are there tightened up by nuts until they find a proper bearing. This construction affords facilities for securing equality of strain which is not found when tee irons are used as previously described.

The nut should in height be fully equal to the diameter of the screwed end, and when tightened up is to be secured by a lock nut, or else by a small pin passing through nut and bolt.

k is the eye end of one of the ties. The eye must be proportioned as follows:—as the eye passes between two lugs, the bolt will be in double shear, and must therefore have a section area equal to half the sectional area of the tie *k*.

Let D = the diameter in inches of the tie; D_1 = do. of the bolts; then,

$$D_1^2 \times \cdot 7854 = \frac{D^2 \times \cdot 7854}{2} \therefore D_1 = \frac{D}{\sqrt{2}} = \frac{D}{1.414} = 0.707\ D.$$

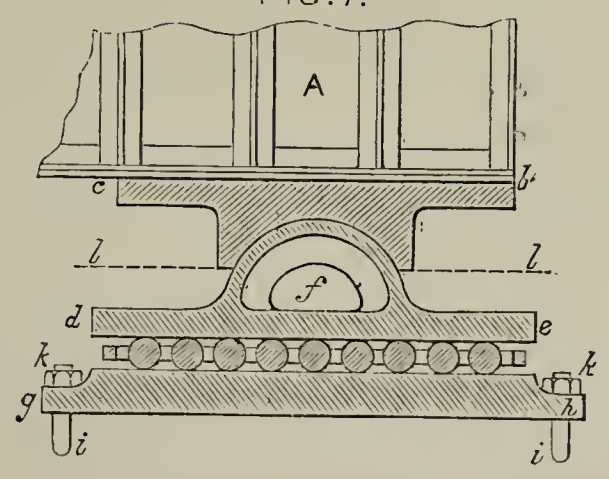
which will be the diameter of the bolt hole *g*, to fit which the bolt is to be accurately turned. The eye will be made flat, its thickness equal to the diameter of the tie rod; its breadth equal to the diameter of the bolt plus the two thicknesses *i,i*, together equal to the diameter *k*, thus giving a slight excess of area at *i,i*. It has been found by experiment that the right proportion for the distance *h* is one and a half diameters of the bolt.

Piers consisting of grouped columns can be very readily erected, scarcely any scaffolding being required beyond a few planks, and a derrick pole to lift the work into position, for as each tier is completed, it forms a platform upon which to start with the next, and the work thus admits of being rapidly pushed on.

We will now consider the superstructure, and in the first place must be determined the size and general arrangement of the bed plates upon the top of the pier, taking them first for discontinuous girders, and in fact for continuous girders we have merely to add together the lengths that would be required for them if discontinuous.

There are certain movements occurring in the freely supported ends of girders that must be provided for in the bed plate arrangements; these are,—expansion and contraction under variations of temperature, and deviations from the horizontal position of the underside of the girder, accompanying deflection under passing loads. A longitudinal section of a bed-plate accommodating both the movements is shown at Fig. 7. The main girder terminates at *A*, its end resting on a

FIG. 7.



cast iron plate *bc* to which it is securely bolted. The underside of this plate is made with a cylindrical concavity as shown, which fits upon the cylindrical segment *f* forming part of the bearing plate *de*. The bed plate *gh*, is secured to the top of the pier or abutment by the bolts *ii*, and upon it are a number of rollers kept at proper distances from each other by side bars having notches, in which pins at the

ends of the iron rollers work. The rollers, which we prefer to make of wrought iron, should be disposed as closely as possible together in order to give the greatest number of points of support to the plate *de*, which rests upon them. The bearing upon *f* allows the end of the girder to deviate from a horizontal position and yet bear evenly upon the plate *de*, and the rollers permit of free expansion and contraction. The rollers will be required at one end only of the bridge, but the bearing *f*, at both ends. If the girders are continuous, fixed bed plates will be put on the centre pier, but all the other piers must be furnished with expansion rollers and every bearing must have the oscillating arrangement *f*. In the English climate the travel to be allowed the plate *de*, must be some thing in excess of $\frac{1}{1800}$ of the total length of the girder from the fixed bed plate.

The size of the bed plate will depend in great measure upon the material of which the pier or abutment is composed. Assume for instance that the bridge is 200 ft. span, formed with two main girders and carrying a double line of railway, then with a full load the total weight on the four bed plates will be

Main girders	320 tons
Cross girders	88 ,,
Ballast &c., ...	144 ,,
Floor plates	29 ,,
Running load	580 ,,
	1161 ,,

that is, 290 tons upon each bed-plate. In what may be called the end pillar of the girder, taking compressive working resistance at 4 tons per square inch, 72.5 sq. in. of horizontal sectional area will be required, and there should be the same bearing on the rollers, the strip of bearing surface of each roller will be very narrow, being only the amount by which it is flattened to the surface of the plate *de*, by pressure. The determination of the number of rollers to be used is more a matter of experience than calculation, as the amount of compression does not admit of the application of formulæ, so the size of the bed plate being fixed upon, the best way is to put in as many rollers as we can. The sectional area of the bearing *f* on the line *l*,*l*, can, however, be calculated. Taking the working strain at 6 tons per sectional square inch. the area required will be, $\frac{290}{6}=48.3$ square in. Such a girder as we are dealing with would be made 2 ft. 6 in. wide, and that would be the transverse length of *f*, the sum of the thicknesses will be $\frac{48.3}{30} = 1.61$ in., we should not, however, make such a casting less than $1\frac{1}{4}$ in. thick on each side. If the bed-plate *gh* be made 6 ft. long by 3 ft. wide, there would be a pressure of $\frac{290}{18}=16$ tons per square foot nearly, which would do well enough if carried on an iron pier, but if on masonry, would require spreading over a larger area, by putting the bed-plate on large thick stones, so as to give a surface of 8 ft. by 5 ft. which might be made up of two stones each 5 ft. by 4 ft. laid side by side, and 2 ft. 6 in. thick. These stones immediately under the bed-plate *gh*, must themselves be very solidly bedded upon the masonry below, and in like manner the cast iron bed-plate truly set upon the stones, any hollowness of bed being fatal to the stability of the work.

The top plate *de*, may be 5 ft. 6 in. long, and thick enough to resist any tendency of the part *f* to shear through it: in so doing it would shear two sections. The safe resistance of cast iron to shearing force is $1\frac{1}{2}$ tons per sectional inch, hence the area of the two sections should be $\frac{290}{1.5} = 193$ sq. in , or $96\frac{1}{2}$ sq. in. in each section. The plate *de*, will spread to 3 ft. wide the same as the bed-plate, hence the requisite thickness will be $\frac{96.5}{36} = 2.68$ inches.

The rollers must be very accurately turned to gauge so that they may be of exactly the same diameter, or where it can be done it is advisable to turn them all in one length and subsequently cut them down into the sets required for each pair of bearing plates.

Other methods of allowing for expansion and contraction have been devised, but our preference is for rollers for bridges of any magnitude.

A viaduct has been erected (on the Continent) in which *rocking piers* are used. The lower ends of the piers have circular segmental beds upon which they are free to oscillate through a certain arc. This is bad in several respects, for in one direction the pier has evidently no stability whatever, and regarding it as a pillar or strut it is much weakened by having a round instead of a flat base.

Before entering upon the consideration of the superstructure in detail, some remarks upon bridges of two or three spans of fixed dimensions are called for. By fixed dimensions it is inferred that the designer has no option as to the length of the spans, or that they are limited in some particular direction.

Suppose that a bridge is required to cross a river and a roadway in two spans, the river being 150 ft. wide, and the road 30 ft. wide; the exigencies of the case being such that the river must be cleared by one span. If it is suggested to make the girders continuous, a fresh matter for consideration will arise, which is the effect of a full load upon the large span on the stability of the smaller one.

Let the bridge be designed to carry a double line of railway, girders being placed under each rail, then the weight of the thirty foot span with flooring, ballast and parapet or handrail will not exceed 39 tons, of which when the structure is unloaded a certain proportion will be upon each point of support. If now an additional load comes upon the larger span it may happen that its effect will be to lift the land end of the short span clear off its bearings, to bring it down again with a violent concussion as the load moves on to it; this, of course, being frequently repeated would soon bring about

the destruction of the work, hence, when the proportions of the spans show any tendency in this direction discontinuous girders must be used.

We will apply Clapeyron's formula to the case above assumed. On the same data as used for the smaller span we find the dead weight of the 150 foot span to be not more than 363 tons, let the running load be 2.9 tons per foot run for the two lines of railway.

Let M = the moment of strain over the pier between the two spans, l' = the first span l'' = the second span in feet; w' and w'' the loads per lineal foot on the first and second spans respectively; and $m = \frac{l'}{l''}$; then, if the short span be taken as unloaded, and the long one as fully loaded, the values of w' and w'' will respectively be 1.144 tons, and 5.242 tons, and

$$M^1 = \frac{l'^2}{4} \times \frac{w'' + w'm^3}{2\{m^2 + m^3\}} = \frac{30^2}{4} \times \frac{5.242 + 1.144 \times \overline{\cdot 2}^3}{2\{\overline{\cdot 2}^2 + \overline{\cdot 2}^3\}} = \frac{900}{4}$$

$$\times \frac{5\cdot 251}{\cdot 096} = 225 \times 54\cdot 7 = 12{,}307 \text{ ft. tons.}$$

Taking the whole length of the shorter span, including bearings as 34 ft., its total weight will be $1.144 \times 34 = 38.89$ tons, and multiplying this by half the length 17 ft., it is found that even when lifted off its land bearing by the deflection of the large span it could only give a moment over the pier of 661.13 ft. tons, so would be of very little service in strengthening the large span.

It is out of question to anchor the land ends of the short girders in this case as the additional strain upon them and its altered character would counterbalance all advantage gained in the larger span.

The test formula for stability may be somewhat simplified. The moment of strain over the pier when the land end is just lifting clear of its supports is $M' = \frac{w' l'^2}{2}$ hence it will be just on the point of lifting when,

$$\frac{w'l'^2}{2} = \frac{l}{4} \times \frac{w'' + w'm^3}{2\{m^2 + m^3\}}, \therefore w' = \frac{w'' + w'm^3}{4m^2 + 4m^3}$$

$$\text{and } \frac{w''}{w'} = 4m^2 + 3m^3.$$

hence the fraction $\frac{w''}{w'}$, must not exceed $(4m^2 + 3m^3)$, and of course for stability it should be somewhat less.

MR. C. BERGERON'S PERMANENT WAY.

THE following interesting paper by Mr. C. Bergeron will be useful to those who are now considering the question of iron permanent way.

For a great number of years I have felt persuaded that the permanent way now in use all over the world is defective, and requires reformation, if passenger trains, with all possible security, are to run over it at higher speeds than are generally in use at the present day.

The improvements which I suggest consist:—

1. In the nature and distribution of the ballast which forms the foundation of the permanent way.
2. In the substitution of an iron sleeper for one of wood, of novel design, for supporting the rails.
3. In the manner of fastening the rails to the sleepers.

I shall consider, one after another, these three propositions, and hope to show how their adaptation could be made very advantageous to the Railway Companies.

1. Ballast.—The question of the ballast as the foundation of the permanent way is, in my opinion, the most important, and I base upon it most of the advantages of my system.

I propose to excavate for each line of rails in the platform of the railway, two trenches, $1\frac{1}{2}$ foot in depth and $1\frac{1}{2}$ foot in width. (*See* Fig. 1.) Plate CLXI.

These trenches will be filled with well-washed sand, and the latter pounded down by means of a rammer, or by compressing rollers. The grains of sand will become so tightly wedged together that rain will no longer be able to disturb them.

In this manner, two walls, so to speak, of soft sandstone will be obtained, into which the blade of a knife will readily enter, and which at the same time will be capable of resisting considerable vertical pressure. It is upon these walls that the sleepers of the rails would rest. In curves, the sand walls beneath the outer rail will require to be made higher by so much as the outer rail will be raised above the inner.

Failing sand extracted from rivers or pits in the neighbourhood of the railway, the very smallest of stones or bricks, crushed into dust by machinery, may be used.

2. Metallic Sleepers.—The sleeper consists of two cast iron troughs, 2 feet long, 10 inches wide, and 6 inches deep, cast at the blast-furnace like ordinary railway chairs, and held together by two iron bars, 2 inches high and half-an-inch thick, intended to maintain—by means of pins set against the vertical sides—the troughs, and thereby the whole line, at the proper and desired gauge.

If, in curves of small radius, it becomes desirable to widen the gauge, this can be done by using cross-bars, in which the pin-holes have been set further apart. Each trough has, upon its whole length, a projecting jaw cast on,

which is shaped like, and does the work of, the ordinary fish-plate, and which serves as a support to the rail.

The two combined troughs, which form the sleeper, will appear as in Figs. 2, 3, 4 and 5.

After having been firmly put together, the sleepers are placed upon the walls of sand, where they are intended to remain.

Each one will be covered by a wooden block, and will then be sharply rammed down by a rammer, like a pile, which it is desired to set deeply in the sand. The vertical sides of the troughs will readily penetrate through the sand, and after a sufficient number of blows the top plate will plant itself firmly upon the top of the sand and there rest. No amount of subsequent ramming will force the trough lower down into the sand.

A cross-section of the line, after the sleepers have been finally laid, will appear as in Fig. 6.

Each trough will, so to speak, form with the sand compressed between its vertical sides, a metallic seat, a kind of anvil, as immovable as the granite base of the foundation of an edifice. It will yet have a sufficient elasticity, because it rests upon a dense layer of sand, and may be compared with the streets of a town, where the paving stones are capable of withstanding the heaviest traffic because they rest upon a layer of sand. I think I am right in stating that a line of rails supported for two-thirds of its length by sleepers, such as I have described, will not experience any vertical or horizontal displacement, whatever be the weights or speeds of the locomotives passing over them.

The troughs will be 2 feet long, and they will be placed at 1 foot distance one from the other. After being laid the sleepers will appear in plan as in Fig. 7.

3.—Fastening of the Rails to the Sleepers.—The rails will be delivered at their place of destination with the bolt-holes, by which they will be fastened to the sleepers, ready punched at the works where they were rolled. By reason of the dimensions of the troughs before mentioned, and of the distances at which they will be placed, the rails will be rolled in lengths of multiples of 3 feet. (*See* Fig. 8.)

The holes will be punched exactly at the desired distances here given. At the point where two rails join, the vertical jaw upon the trough will act as a fish-plate, and a single bolt will hold the two ends of the rail together, as shown in Fig. 9.

In curves, the same troughs as before described may be used, but the groups of three holes corresponding to those of a trough must be brought nearer together. These rails may be punched somewhat as shown in Fig. 10.

Rails of this description will be used in sufficient numbers to make up the difference in length between the outer and the inner line of rails.

I believe that it will be advisable to use a bull-headed rail, with unequal heads, as such a one is bent in the horizontal sense more easily than the flanged Vignoles rail. (Figs. 11 and 12).

It is not intended to be turned; the upper head, could, therefore, be made of the same section as the heaviest rail in use upon English railways.

Its height will be 4 inches, and as its unsupported interval between troughs, where it is, so to speak, encased, will only be 1 foot in length, it will, with a weight only of 50 lbs. to the yard, offer as much resistance to bending, in the vertical sense, as an 80-lbs. rail of $5\frac{1}{2}$ inches in height, which is supported upon sleepers placed $2\frac{1}{2}$ feet apart.

It is easy to perceive the economy which is likely to result by replacing, when the upper head is worn, a rail of 50 lbs. to the yard in the place of one of 80 lbs., which would not have lasted longer.

When the cast-iron troughs of the sleepers have been driven like piles into the compressed sand which forms the foundation of the permanent way, the rails will be placed upon them, one after another, care being taken to put the joints always into the centre of the trough.

The holes in the rails must exactly correspond with those in the vertical jaws of the troughs. The bolts will then be put in, the heads of which are square and will be placed against the inner side of the rail. Spring-nuts will hold the rails as firmly as possible to the jaws of the troughs, which will then act like fish-plates.

The permanent way will then be finally laid. It will appear in plan, and in longitudinal elevation and section, as in Figs. 13, 14, and 15.

Under these conditions the line will be as solid, and will require as little maintenance as if it were placed on the girders of an iron bridge. The rain water will flow outside the line and pass under the rails between two troughs, by means of channels made for the purpose.

The road will finally be covered with earth and sown with grass. Whatever may be the weight and speed of the trains, they will pass over without shocks, without oscillation, and without raising clouds of dust, like sledges over a frozen lake. Independent of a solidity proof against every pressure, the permanent way which I would propose, laid with rails of 50 lbs. per yard, will be more durable and will cost less to construct than the ordinary way with wooden sleepers, and with rails of 80 lbs. to the yard, and cast-iron chairs of 40 lbs. in weight.

In calculating the cost price of either system, I find a saving of about 5*s.* per yard in favour of my improved system; and once constructed and open to traffic, it will cost nothing more for maintenance until the time when it becomes necessary to change the steel rails—that is to say, at the end of some twenty years on the hardest-worked lines.

The advantages likely to result from the improvements which I propose may be enumerated as follows:—1. A considerable reduction in the size of the formation, which, for a

single line, will be only 13 or 14 feet in width, instead of 20 feet, which is given when using a layer of 2 feet thick of ballast, and sleepers 9 feet in length placed upon it. 2. An immovable and yet elastic foundation for the cast-iron troughs which form the supports of the rails, instead of placing the wooden sleepers upon a layer of ballast without adhesion, which gives way unequally, and which requires frequent packing, in consequence of which the two lines of rail are subjected to perpetual oscillations by reason of the unequal resistance of the sleepers to the passage of trains. 3. A reduction in the weight of the rails, which would be only 50 lbs. per yard, instead of 80 lbs., as at present in use upon the principal railway lines. 4. A very great saving in the maintenance and the repairing, as against the present system, which requires the continual presence of a large number of plateplayers, the work of which would be replaced by a service of overlookers only. It would be easy to discover further and perhaps greater advantages in entering upon the question of diminution in the wear and tear of tyres, springs, and general moving parts of locomotive engines and carriages. It is particularly in the gentleness of the rolling motion of the carriages over a perfectly even and regular road, that passengers could appreciate the pleasures of rapid travelling, without shocks or jars, and without any danger of running off the rails.

I do not, therefore, hesitate to submit these proposals of improvements in the permanent way to the notice and judgment of engineers who have to construct or work railways, merely requesting them to make a trial on a length of several miles. By such a trial, the problem of a cheap road, perfectly proof against disturbance in every respect, would soon be solved.

N.B.—It has been suggested to me that there might be some difficulty in adjusting the holes in the rails to correspond with those in the troughs or sleepers after they are laid. I have therefore changed the form of the sleepers, and the manner of fastening the rails. These modifications are shown in Figs. 16, 17, 18, 19. The rails are fastened by means of keys of compressed oak, held by vertical jaws, cast on the troughs as in the case of ordinary chairs.

The joints of the rails are placed between two consecutive sleepers, and the fish plates are so arranged as to project beneath the lower heads of the rails, in order to increase their strength and give greater support at the joints, as is shown in Figs. 18 and 19. In the top plate of each sleeper in the spaces not occupied by the vertical jaws, there will be three openings of 4 inches in length, and one and a half inches in width, which will permit an examination of the sand foundation after the sleeper is laid. Should it become necessary to raise a sleeper which has sunk too low, this can be done by packing sand into these holes with tools similar to those employed in caulking ships.

The general principles laid down in the above apply to this improved system, whereby the laying of sleepers is simplified, and compressed oak keys suffice to fasten the rails to the sleepers.

London, July 18th, 1882. CH. BERGERON.

THE SUSPENSION CAR TRUCK.

AN American Correspondent gives the following account of a new truck, which we propose to illustrate in our next issue.

"The 'Suspension Car Truck' has been in use on many of our railroads for about three years past. Its construction and work has been studied and watched by some of the most conservative and experienced mechanics and engineers in this country: and their unanimous testimony as to its merits is, that 'It is the best and safest truck they have ever seen, or used; obviating the great defects in the rigid and swing beam trucks, and giving advantages in the carrying of loads, which have been sought for for over thirty years, but never before obtained.'"

Under severe tests and long continued use; under very heavy loads, and every condition of road and track; on tangents, short curves, on the best and the worst of road beds; at high and at low rates of speed, this truck has proved itself the safest, easiest riding, and most economical, ever made. It differs in construction, in some material points from the present truck, in having no centre-plate, or swing beam; but instead, having bearers 42 inches apart laterally, and the car body hung on links, having longitudinal and swivelling movements only.

It differs also, in that the truck-frame is hung on links over the axle boxes, having a lateral movement only, by means of which, lateral motion is prevented going up into truck-frame or car-body.

The object of the invention is—to carry the load with as little movement as possible. In order to do this, we provide that all the movements be made by the lighter parts, to the heavier part, viz.: the car-body; and be controlled by it.

Upon curves, the lateral movement of the first pair of wheels and axle, and their parts,—does not carry the load with it directly, but indirectly one-half the movement of the first wheel, *throwing the links* on the first pair of wheels, at an angle to the *right;* the movement of the truck frame throws the rear pair of links at an angle to the left: when

the rear wheels gets to the point of track where the first pair diverged, the centrifugal force of the body of the car throws the *rear pair* of links at an angle to the right, and holds it there till the resistance is taken away from the first pair of wheels; consequently, the action of the box links is directly the opposite to that of a swing-beam and centre-pin truck.

The lateral movement of the first pair of wheels of the "Centre-pin truck" is to throw the rear end of the truck-frame against the outer rail, causing the quick lateral thrust to be imparted to the swing-beam, and by it communicated to the car body, making it go further than it otherwise would, then to react to the inside of the curve, back again repeatedly, until the effect of the blow dies out. This blow is not received at all by the Suspension Car Truck, being swung off on the rear pair of links.

With this truck, on a straight line, all the lateral movement produced by irregularities in the rails, *is lost by each pair of wheels when it comes to that point* on the rail; and its transmission to the car body or truck frame prevented.

The ordinary construction, or *centre-pin truck*, compels the truck-frame to move laterally with each movement of any given pair of wheels, after the end freedom of the brass is taken out; which greatly *increases* the violence of the concussion on the track and on the rolling-stock, and carries the shock up to the car body.

In the Suspension Truck, the *truck frame* is hung on links, resting on the axle-boxes, allowing *wheels and axles free lateral motion*, though they are absolutely rigid in the line of travel.

To modify and soften the force of concussions and disturbances, in the position of the truck lengthwise, relatively to the track, the mode of connection allows freedom for the truck to move forward and backward, within considerable limits relatively to the car. It is a means, additional to the springs and other devices, introduced to soften the concussion of the car arising from the passage of the wheels over any obstacle or irregularity. The *car body*, therefore, is also hung on links, giving it an easy longitudinal motion. The bearers on the trucks, for the car body, have a longitudinal bearing of about thirty inches, and a lateral bearing of from thirty-nine to forty-two inches. This modifies and improves the provisions or swivelling, or turning partially around of the truck, relatively to the car. This has heretofore been effected by centre plates, king bolts and side bearings, which are dispensed with in this truck, enabling the weight of the car body to aid in controlling the trucks on curves, and thus easing the flange of the wheel from the outer rail. The weight of the car body is at the lower end of the link, or pendulum, and in diverging from straight lines, at high rates of speed, this invention brings the gravity of the truck and cars into an actual and direct opposition to the centrifugal force, which relieves in great part, or entirely, the outside rail from such force. In rounding curves, the push or pull, as it comes, is between the centre of the truck and the wheel on the outer rail of a curve, and such push or pull, together with the resistance of the gravity of the car and truck to the centrifugal force, relieves the outside rail from the same, making the draught almost as light as on the straight track, the motion of the truck and wheels, being controlled by the weight of the car and load, instead of, as at present, the truck's motion entirely controlling the car body.

We thus have a perfectly easy, lateral motion of the wheels, which prevents it being transmitted to the car body—an easy, longitudinal motion, subject to the weight, and an easy swivelling motion, also subject to the weight, when either entering upon or leaving a curve. The result is, an easy smoothness of motion, and a reduction of friction, which have never before been attained.

In this truck, the brasses have no end play, and axles and boxes move simultaneously, thus saving end wear on brasses. The weight of the truck frame, car body and load, tends to maintain the links over the axle boxes in a vertical position, and this tendency cannot be neutralized as long as the car traverses a perfectly straight track, as gravitation controls it; but when a car reaches a curve, or uneven portion of the track, there will be a tendency of the wheel to move laterally, when the box link will assume an inclined position. But the link cannot be moved from a vertical to an inclined position without slightly raising the frame and body of the car, so that there is a tendency, on the part of the frame, to restore the link and box to their normal and vertical position. This tendency, however, is not of an abrupt character, but so easy as to obviate objectionable shocks, which, in ordinary cars, are due to the constant contact of the axles with the ends of the bearings, in the boxes. In other words, the lateral play of the axles is not resisted with the usual abruptness, which results in disagreeable shocks; but gently, by the weight of the car, which really acts as a cushion. The upper links under the body bearers, have the same action longitudinally, and control the lower links through the weight of the car body; the tendency of all links is to go to a plumb line, thus giving a much easier motion when starting or suddenly stopping the car; the two together preventing the usual shocks or jars, due to imperfection in surface or alignment of the track, and producing an easy, steady and uniform motion of the car, either on the straight track, or, when entering upon rounding, or leaving sharp curves.

The outside wheels on a curve are, by the centrifugal force throwing out the body of the car, kept easily and closely up to, and in the alignment of the outer rail, thus avoiding the zigzag or jerky motion of the "centre-pin truck," produced by the swinging out of the body by centrifugal force, and in repeatedly, by force of the blow received in the ends of the brasses, which is the only way the rigid truck can pass around a curve at a high velocity. The action of the links on the Suspension Truck, allows the body to swing

out, and centrifugal force holds it there, until it leaves the curve at a tangent, when the weight straightens out the truck, without its going to the inner rail, thus reducing all flange friction to a minimum, and very greatly reducing the draught of the cars, both on curves and on straight tracks.

One feature of importance is, that in passing around a curve, the draught is always from the outer line or bearing, thereby lessening the strain against the rail and flange.

In the centre-pin truck, if the rub-irons bear, there is an undue friction ; if they do not bear, there is a top-sway to the car. The Suspension Truck has neither. Its wide bearings under car bodies longitudinally and laterally, give great strength to car body, and perfect steadiness of motion, without undue friction, though under a broader base ; as the load is hung on the upper links, which swing easily, to round all curves.

Its action under load, so far as railroad car motions are concerned, is almost that of a universal joint, as the truck, under control of the car body, adjusts itself to every change of condition of the road-bed, with the greatest ease and safety, and without shock or jar to car or load. With all other car trucks, the irregularities of the track cause the whole truck-frame, with its weight of car and load, to run from one side of the track to the other, causing violent concussions, the shocks of which increase with velocity ; very much increasing the traction, and injuring both track and car.

With the Supension Car Truck, each turn of the wheels accommodates itself to the curve of the track, by moving easily from side to side, under the car and truck, suspended on the box-hangers.

The lateral movement of the wheels and axle imparts, even upon the roughest and most irregular track, little if any side motion to the car ; as the rail, coming in contact with the wheel flanges, has only to throw over the wheel axle, moving laterally on their links ; instead of, as at present, the whole load, and producing (instead of the shock of the rigid truck) slight variations in the hang of the link only. The difference in concussion is very nearly the difference between a blow struck by a hammer weighing 1,500 lbs., and one weighing 60,000 lbs., three-quarters of a ton against 30 tons.

The connection of the car body with the Suspension Truck is such as to prevent the possibility of the truck, in case of derailment, turning round at right angles to the car. as is often the case with ordinary trucks ; and, turning over, and making what would otherwise be a slight accident a serious and expensive wreck. In this truck, on the contrary, it is held by its bearings, square in the line of travel ; and, though it should happen in a collision or other serious accident, to be derailed ; the wheels would be kept nearly parallel to the track, so long as the truck is fast to the body, giving much greater security than the safety chain.

Where curves occur, the additional traction due to the curve becomes a serious and important matter ; how important is best shown by the fact that a careful and probably correct calculation proves that a reduction of 25 per cent. of the traction on all trains on the Lake Shore & Michigan Southern Railroad on the traffic of 1873, would have effected a saving of over 750,000 dollars, and that the saving of one pound of tractive force per ton on the railway tonnage of the United States, would effect a saving of many millions of dollars every year.

The amount of flange friction is an open question, and heretofore has not been separated from the rolling friction on the rail ; or, in other words, the outside rail is longer than the inner, and as both wheels are fast to the same axle, one or the other must slip at the same time that they have the greatest flange friction. But we hope, by future experiments, to separate the two.

We show a very large percentage of reduction of tractive force required.

The evils of rigid trucks have been long known, and devices earnestly sought to remedy them, and find a satisfactory substitute. The substitute, by which these defects are almost, if not entirely overcome, has not been found until now. The combined swivelling action of the upper links of the Suspension Car Truck, with the lateral action of the lower links, meets every difficulty, and gives the minimum of friction.

These trucks are so constructed that, though the axles are absolutely rigid in the line of travel, the wheels are easily and automatically turned to the line of the curve, reducing the slip of the wheel, and the friction of the flange upon the rail, to a minimum, and thus reducing the traction of the cars, until it is but slightly more upon a curve than upon a straight track ; and the sharper and more difficult the curve the greater is the proportion of saving and reduction of curve friction made by the use of this truck.

An important feature of the Suspension Car Truck, is the provision by which the lateral motion, so unpleasant to passengers and so damaging to rolling-stock and track, is entirely prevented. A large proportion of velocity resistance is due to oscillation and concussion on the straight track ; that from concussion alone amounting to half a pound per ton, at ten miles per hour, increasing with the square of the velocity. Oscillatory resistance varies very nearly with the weight, and at a speed of ten miles per hour is found to be never less than half a pound per ton, on all lines, under all circumstances. Additional flange friction, which, in ordinary trucks, results from the oscillation of the truck upon its pivot, is an element of resistance incapable of exact computation. It prevents the wheels from adjusting themselves to their proper position on the track, and continuing adjusted, around the curve. These oscillations

occur upon straight lines, but more especially on curves, where the impulse given to the wheel in changing its direction, drives the truck diagonally towards the opposite rail. These oscillations cause the wheel flanges to impinge, first, on one rail, and then on the other, and thus add to the resistance and prevent the coning of the wheels from being continuously effective.

With the Suspension Car Truck this does not happen. The radial or twisting movement of the whole truck, when on curves, and the free side play of the wheels and axles, allow the complete adjusting of the trucks to the radius of the curve. Yet, when on straight lines, the trucks run perfectly smooth, with no tendency to diverge from the track; the wheels and axles, sensitive to the slightest obstructions, pass them without jar or shock to the car body, and, the weight always controlling, keeps the load in the centre of the line of travel.

The importance to stockholders of any device or construction of car trucks which should materially diminish the resistance upon curves, and the oscillatory resistance, both upon straight lines and curves, as well as the wear and tear of the rolling-stock and track, will be appreciated when a careful comparison is made, even between roads using different classes of rolling-stock now in common use. The economy in the use of improved rolling-stock is forcibly illustrated by the fact that, on one road, where the defects of track made the average resistance 57 per cent. greater than upon a connecting road, by the use of improved rolling-stock and locomotives, the work done per pound of coal is now 50 per cent. greater than on the good roads.

The use of the truck will effect a very great saving over that of the very best rolling-stock now in use. All experiments thus far made show a large percentage of reduction of resistance.

The strength of the truck is not the least of its recommendations. By reason of its wide bolster bearing, and its perfect proportion of parts, and careful distribution of strains, it will carry with entire safety more load than a common truck; from the fact also that it takes all jars, shocks, or blows as would a cushion or spring, no part is subjected to the same strain in service as in the common truck. So much is this the case, that Suspension Trucks which have been two years in constant service, have never had a cent's worth of repair put on them, and some of them have never even had a wrench on them to turn up a nut; while other trucks, on the same roads, have to be looked over, repaired, or the nuts screwed up, after every long trip; and besides this, the saving on wheel flanges is very marked.

The truck will be so constructed as to have all the parts interchangeable, and lettered and numbered, so that any part of any truck will perfectly fit any other truck of the same number and class. This will secure absolute uniformity, where hitherto there has been the widest diversity.

The many advantages of the Suspension Car Truck, over any other truck used, have commended it, and secured its approval as the standard truck wherever it has been tested; this uniformly so, and without a single dissenting opinion; and will, we confidently believe, secure its adoption and use on every railroad in the United States, as rapidly as they can be built for new rolling-stock, or substituted for trucks now in use. Their use under passenger-cars has given very great satisfaction. From one road, which has been using them for some time, we hear as follows: "I will say that their action is as near perfection as possible. They run very steadily and smoothly..... While running at high rates of speed, unless you are watching the track, you will be unable to tell when you are entering upon or leaving a curve, the motion of the car being entirely imperceptible." In this particular, the interest of the Railroad Companies will be subserved, at the same time that they provide the easiest, most comfortable, and safest rolling-stock for the use of the public."

The Suspension Car Truck Manufacturing Co. will have their car trucks built with special tools, and facilities for building rapidly, and, at the same time insuring exactness and perfect mechanism; and with an economy which will enable them to supply car builders, or Railroad Companies who build their own cars with all the parts of trucks, less the wheels and axles, or, with the trucks completed, as they may desire, at prices much lower than they can be produced in shops not specially fitted for building this truck.

The characteristics sought for in a "Standard Truck," and to which all improvements should tend, are, briefly:

Safety, under every condition normal to a railroad, up to the highest attainable rates of speed on curves, tangents, and switches.

The greatest possible safety, under extraordinary conditions. It should not be easily thrown from the rails, and if derailed should keep the wheels parallel with the track, and not turn round at a right angle.

The strongest possible connection with car body, so that in case of collision, car body and truck would not be disconnected.

Adaptability of movement, or quickness of adjustment to rails, under varying conditions;—it should adjust itself automatically and promptly to curves or irregularities, and in the same way, straighten out promptly on leaving curves and entering on straight track; giving,

Ease and smoothness of motion; pleasant to ride on.

Absence of jar and shock; and without the lateral thrust which imparts so much friction, and rapidly wears away brasses.

A movement almost as easy on curves as on straight track.

Prevention of top-sway (especially valuable for Narrow Gauge Cars).

It should utilize weight of load, against centrifugal force; one natural law against another.

Its construction should be characterized by simplicity, strength, and lightness, great width and breadth of bearings, giving steadiness and safe strong connection with car body.

That every part be interchangeable in all trucks of a class, with every other like part; perfectly fitted and manufactured, so that for repairs, when required, it should be cheap and convenient.

All parts should be easy of access, and the breaking of one part should not necessitate the removal of or interference with others.

Economy in repair and maintenance should be a prominent feature of the standard truck; its parts should have the minimum of friction; and in motion its wheels should have the minimum of friction on rails and flanges. This being obtained must of necessity lead to much saving of labour;

To economy in wheel flanges;

To saving in end wear and brasses—in wear of rails and road-bed, in car-bodies and truck frames, in traction, and generally in expenditure for maintenance and repair.

A truck answering the foregoing requirements would, without controversy, be the best working and most economical truck now in use—and from every point of view, whether of safety, ease and pleasantness of motion, or economy, it should unquestionably be the "Standard Truck" of the United States.

That the "Suspension Car Truck" possesses these essentials, as far as it is possible to obtain them under the conditions and limitations of service, is apparent to all who have examined its principle, as well as carefully observed and tested its working.

Railroad interests are the most important and extensive in this country. They reach out to, connect, and develop every part of it. An immense amount of capital is invested, and some of the best talent in the world engaged in its management and in every department of its working.

In the United States alone there are over 600,000 pairs or sets of car trucks now in use, and about one hundred and twenty large factories employed in the manufacture of railroad cars, replacing those worn out, and supplying increased rolling stock; and, with new lines of railroads continually constructing, with a country developing in a manner so unprecedented; and with ever-increasing growth by emigration and otherwise—this immense number of trucks in use will, in a few years, appear small in comparison.

We may add to this another continent, South America, which the enterprise of some of our leading railroad projectors has already opened up as a market for American Railway Rolling Stock and supplies.

These vast fields are the ma kets for our "Suspension Car Truck," and we enter them, supplying a great need, "A Standard Car Truck," with the very best in the world, having improvements and advantages possessed by no other.

It has commended itself to all intelligent, progressive railroad men who have had opportunity to see or to use it, and as was remarked before, this unfailingly so. It is a strong testimony to its real merit that, although it has been brought before very many of the most experienced and conservative railway men in this country, there is not one who has tried it who has not been convinced of its superiority, and of the many great advantages to be gained by its general adoption.

It can be supplied as cheaply as any other first-class car truck. This company owns all patents in any way connected with its manufacture, and is in the market offering what is unapproachably the best "first-class truck" for passenger and freight use at no increased cost.

SYNOPSIS.

Construction.—The Suspension Car Truck is constructed, except as to its special devices, as near as possible to the best present standards for passenger and freight trucks; with standard wheels, axles, axle boxes, etc.

In Passenger Trucks, the main difference being, first, the not using of centre plate and king-pin, rub irons or swing beam; but, instead, broad bearings, 44 inches apart laterally, allowing no lateral motion between car body and truck. The car bodies are carried on links, having longitudinal and swivelling movements only.

Second: The housings are a little longer and wider than in the standard passenger trucks, giving space for side links, which are placed over the axle boxes, allowing free lateral play to wheels and axles

The Freight Trucks are constructed with standard wheels, axles, etc., and with either wooden bolsters, or channel bar bolsters; the side frames being almost the same as the diamond truck. The ends of the frames are not rigid to the boxes, but are attached to the swing links, as in our passenger truck.

ADVANTAGES.

Greater safety under every possible condition.

Wide lateral connection, preventing the turning round of trucks under car, when derailed.

Ease in curving.

Elimination of lateral motion of car body, either on tangents or curves.

Absence of jar and shock.

Prevention of top sway.

Minimum of friction of parts.

Utilization of weight against centrifugal force.

Simplicity, strength, and lightness of construction.

Economy in wheel flanges, rails, brasses, etc.

Saving of tractive force.

Economy in repair and maintenance.

For passenger cars, pleasantness and ease of motion.

Absence of shock and swing on curves.

For narrow gauge cars, absence of top-sway; and, perfect safety at high rates of speed.

The action and effect of the axle box links, is directly the opposite of that of the swing beam, in the centre-pin truck.

RAILWAY SIGNALLING.

INTERLOCKING POINTS AND SIGNALS.

(*Continued from page* 180.)

WE now purpose directing our readers' brief attention to one or two practical illustrations of the best recognized systems of railway signalling and traffic management, in their most recent or improved forms, as carried out at some of our principal London termini. For this purpose we would first mention the very admirable arrangements as now perfected at the London Bridge Terminus of the Brighton Railway. The excellent, uniform, and systematic character of this company's appliances in general are too well known to most of our practical readers to need any prefatory encomium.

This comparatively small line, comprising 304 miles of double and 96 miles of single way, worked respectively on the absolute "block system," and in the latter case with the "train staff" combined, affords a very able example of careful consideration for the safety, convenience, and comfort of the railway travelling public. Not only has exceptionable technical ability and time been expended by the various heads of the company's staff to study, as far as their no small personal experiences extend, to ensure the safety and general welfare of their passengers; but we find by analysis that their enterprising views have far exceeded the usual accessions to most, if not all, the latest requirements of the Inspecting Officers of the Board of Trade.

The present arrangements and appointments of the London Terminus of the Brighton Railway have engaged the attention of no few minds of ordinary calibre, and are the results of the combined intelligence of many of the most able railway men both at home and abroad.

Brighton being considered the queen of our Southern seaside resorts, with its great and unequalled accessibility to our vast metropolis, has rendered the main-line passenger traffic of this railway probably without precedence in its magnitude. However, very few of the many thousands of persons who entrust themselves to the services of such modern locomotion have any idea, or indeed care, how many years of intelligent and unceasing application have been bestowed on it, in order to ensure the degree of safety their transit of to-day has obtained.

In holiday times, when great pressure of traffic is thrown upon our railway systems, it is by no means uncommon to be inflicted by ignorant and irresponsible interrogations and exclamations such as "What are we waiting here for now?" or, "I could manage a line better than this," &c. But the remarkable point is that such examples of the travelling public which are thus spasmodically inflated with their own importance and capabilities, are totally devoid of the most elementary initiation of any of the really marvellous requirements and accomplishments of the modern machinery of railway locomotion.

At many of our large railway termini it is common to control the reception and departure of from 550 to 600 trains per day, which is no mean attainment in the practice of railway appliances, management, and discipline. At the London terminus of the Brighton line upwards of 560 trains are received and despatched throughout every working day, and, as many of our readers are aware, there is here adopted one of the most perfect systems of signalling in the world—one which reflects the greatest credit on all concerned.

This terminus boasts of probably the most colossal concentration of railway signalling apparatus ever achieved. The whole traffic to and from this station is controlled by the Great North Cabin, in which two interlocking frames forming an aggregate of 280 point and signal levers are brought together so as to be effectually worked by only four men, the distance round such frames being over fifty yards. The re-signalling of this station was commenced about three years ago and took upwards of twelve months to complete, the re-arrangement of the roads being planned by Mr. Williams, traffic superintendent, and carried out by Mr. Bannister, engineer to the line. The signalling arrangements were designed and executed by Messrs. Saxby & Farmer, and form probably the most complete and extensive achievement of the kind in the railway world.

We will now refer our readers to the two Diagrams on Plates CLXII., CLXIII., for practical details of these arrangements, which will be seen at a glance to consist of no small amount of elaborated yet essential elements.

The first diagram represents the ramifications of the terminus roads, with their signalling and safety appliances situated to the east of the Great North Cabin, which, as aforesaid, controls the entire traffic of the station, and which will be seen to be situated at about the middle of the roads a very few yards in advance of the platforms, and in the immediate proximity of the double circles indicating the turn-table directly accessible from nearly all roads.

The second diagram represents the roads situated to the west of the north box, which, with the before mentioned turn-table, now appears to the right instead of the left hand of the station, but which in reality is placed as previously stated, between the east and west arrangement of roads. The apparent complexity of lines will be readily recognized by those experienced in such engineering matters, to present

great facilities for the direction and transfer of traffic, whilst great ability has been shown in the economical utilization of the area to be dealt with.

The terminal arrangements will be seen to consist of eleven platform bays and two sidings, while any particular class of traffic cannot be stated as being exclusively confined to the constant use of any one or more of such roads or bays, for indeed the exceptional accessibility and facilities of transferring traffic are such that any platform may be used according to convenience or requirements. However, under ordinary circumstances the arrival and departure of traffic may be broadly stated to be as follows :—Platforms Nos. 1 to 5 on the west division of the station are usually set apart for the in and out traffic to and from the South of London, *e.g.*, Brixton, Peckham, &c., (*en route* to Victoria), Sutton, Epsom, and Dorking, &c., with some main line trains to Portsmouth and the Isle of Wight. Nos. 1 and 2 (east division) chiefly for main line arrival, and Nos. 3 and 4 main line departure service, while Nos. 5 and 6 are almost exclusively utilized for in and out traffic to stations on the Crystal Palace line.

It should be understood that all roads and bays are used alike for in and out trains while any transfer of usual traffic is entirely dependent upon the occupation of any particular part of the station from local pressure of service or similar causes. The South London trains are, however, kept as much as possible to the west side of the stations, where special provisions are provided for their supply of water and coal in No. 3 siding. The termination of the roads, or buffer stops, are situated where the large numbers above referred to are shown, to the right hand of the diagram in the first Plate, and to the left hand on the second diagram. Conversely in the opposite directions is indicated the concentration of out or down traffic from the station. The direction or nature of traffic over the six principal roads leading to and from the terminus is indicated on each, from which it will be seen that the facilities and accommodation for the up is greater than that for the down trains. This was doubtless occasioned by the limits of lateral extension at the time of construction.

The centrally situated turn-table is almost directly accessible from any road on either side of the station, which is a great convenience for the speedy and safe transfer of light engines, &c. This will be understood by noticing the cross-over or transfer roads ultimately leading or converging towards the turn-table road passing under the north box, so that practically engines may be allowed to almost directly travel from any point east or west to this one common centre of transfer. Leading in a direct line south from the turn-table will be noticed one or more coal or coke and ash pit sidings, &c., but from which point beyond the controlling box no communication exists between the main roads, so that the engines are obliged to again return to within the immediate proximity of the north box before they can get access to any road and permission to pass out. This is obviously a great provision of safety, as otherwise, directly an engine or train had passed clear of a box, with a possibility of getting away further, its presence might be overlooked or forgotten in pressure of other work, and thus a road might be ultimately given as clear when actually blocked or fouled.

As all the station roads are used alike for both in and out traffic, it is obvious that all points of junctions and cross-over roads must be alternately employed in both facing and trailing capacities, and therefore much careful attention has been necessarily bestowed upon the locking and control of such points to ensure the utmost safety of traffic. The situation and use of the various points and crossings are indicated by the black patches upon the diagram. Those used at any time as facing points have corresponding reference on them, with a statement of the number of bolts and locking bars used in connection with them, for the purposes as minutely explained in our previous numbers.

Each platform is provided with and controlled by special arrival and departure signals situated at its end, as shown in the diagram, each road being governed by a separate in and out signal and an auxiliary signal for indicating the condition of any bay, and also for out-shunting purposes. Detail views to an enlarged scale of these arrival and departure signals are shown in one of the top corners of each plate. The lowering of the left hand top signals going into the station indicate the permission for trains to enter certain bays or platforms ready for their reception, while the lower arms or lights respectively indicate by their "on or off" positions whether these roads are absolutely clear up to the buffer stops, or whether partially blocked by standing vehicles. The lowered or "off" positions of the down top left hand platform signals indicate the permission for the departure of certain out trains, and the subsequently similar operation of the lower signals, distinguished by the black rings on the semaphore arms, the permission to light engines detached from up trains to pass and shunt out to sidings to coal or water, or to wait to take on to succeeding out trains, the direction or destination of such traffic being ultimately determined by the position of the points, and the disc signals situated on the girders or on the ground.

Passing further down the roads away from the station on the east side we come to the section and platform disc signals carried by the east girder situated a little distance south of the north box. The detail, nature, and arrangements of these signals are illustrated on a larger scale immediately below the girder at the bottom of Plate CLXII. The semaphore and lamp signals carried by the posts on this girder indicate the right to enter certain of the sections D, E, or F, commanding the approach or departure to and from the station, and it is at these points where

the trains become concentrated, that the drivers learn their definite course and destination. Each section signal controls more than one road, *e.g.*, by the section signal *F* trains may be despatched out of the terminus *viâ* the roads 5 or 6, or in and out by 3 and 4; by *E* in or out of the roads 2, 3, 4, 5 and 6; by *D* in or out of the roads 1, 2, 3, and 4. Now, it will be readily comprehended, that as a train approaches the girder and finds a certain section signal off, the driver learns that he is going in or out of the station *viâ* certain roads, but that some further indication is advisable for him to definitely know which one actually out of the four or five roads open to him, is really ready for his reception. This, Messrs. Saxby & Farmer have ingeniously provided for, by the auxiliary assistance of disc signals, which indicate the ultimate passage or course of the train after passing the section signals. This device was contrived in order to reduce the confusing number of signals which would otherwise have to exist at such a terminus. The construction and operation of these disc signals in conjunction with the slotted gear of the section semaphores has been described in a previous number. In this manner a driver of an in or up train, for example, gets his section signal at some distance from the girder, and upon his arrival at the same obtains from the disc signals a further and definite intimation as to the actual road or bay in the station he is about to occupy. When he passes through the girder, he at once sights his particular platform arrival signal, which should also be off, and by the additional assistance of the position of the lower arm, he now learns whether he has a clear run in, or whether his road is partly occupied by a waiting train, detached vehicles, or a light engine, &c. On the west side of the station an exactly similar state of affairs exists, the sectional signals being mounted on the west girder situated rather further south, and a detail explanation of which is annexed on an enlarged scale immediately below them as in the former example. The sections controlled by these signals are termed *A*, *B*, and *C*—*A* being the key in and out of the roads 1, 2, and 3; *B* similarly 1, 2, 3, and 4; and *C* 1, 2, 3, 4, and 5. The actual road prepared for the reception on any particular line is likewise indicated by disc signals working in concert with the other signals, in the manner previously described. Almost immediately after these sectional signals, and where the traffic is concentrated for final and definite information as to subsequent procedure, the roads converge into the six main lines previously referred to and clearly shown on the diagrams.

At about this point of juncture are situated the usual stop or home signals worked by the ordinary levers placed in a comparatively small south cabin, which are also connected so as to control the operation of many signals receiving their positive actuation from the north cabin; a converse control being likewise effected, the definite particulars regarding which are indicated in italics on the diagrams.

About this locality some advance signals are provided on the west side so as to allow trains to draw out clear of the terminus, and avoid as far as possible any unnecessary obstructions to the passage of any engines or trains at a centre of concentrated traffic of such importance and magnitude. Beyond the stop or home signals above referred to, the traffic is subsequently conducted by a repetition of the same appliances in concert with distant signals at various intervals depending upon the usual requirements in the ordinary manner.

There is another rather striking arrangement in the Great North Cabin worthy of brief attention, viz., the total absence of electrical, audible or bell code signals for guiding the manipulation of the mechanical signalling system. The signalmen in this box learn by the whistling of any engine the desired departure of a train, and consequently apply to the south box for permission for a certain road, which is effected by simply depressing a special electric plunger relating to the road required. If the section be clear ahead the man in charge at the south box pulls off his signal, which mechanically transmits motion so as to turn a disc or plate in the north cabin, thus indicating his prior operation and the condition of the road asked for. The man at the north box can then lower the relative platform starting signal so as to let the train proceed out of the terminus. These starters are also controlled by the man at the south cabin, through the intervention of slotted gear, so as to prevent any conflicting operation between them. "Down Section Disc Signals" are also provided on the platform semaphore posts for giving the drivers of out trains definite instructions as to *via* what sections they will travel on their road to the girder signals. These Disc Signals are marked with the letters of the relative sections to which they refer as shewn on the diagrams by the white letters on the black circles, situated close to the platform signals. The distinction between these Disc Signals and those on the girders will be seen, inasmuch as the latter are provided with the Nos. of the roads and not letters of the sections as in the former case.

It should be further observed that many of this Company's terminus signals are additionally controlled by the South Eastern Company's south signal box, situated rather further to the east and *vice versa*, as for example, those on the west side of the station, and for which reason no "Advance or draw-ahead signals are allowed on this side." All such special arrangements of interlocking and slotting are described in italic notes on the diagrams, which clearly state to what signals such precautions are extended, and which will be found to agree with the numbers of those shown on the various roads.

Similarly, the practical interlocking of the various point and signal levers in the boxes is described in detail on the drawings. So that upon carefully comparing the directions and requirements of the roads with the functions of the relative points and signals, the tables or foot notes of the interlocking or slotting arrangements will serve as a key

or explanation to their otherwise possibly conflicting operations. The whole arrangement of the signals at this terminus are carried out on what is known as the "Spread System," that is, the signals are divided and placed about as separately and distinctly as possible, so as to minimise the liability of drivers taking wrong signals. It will be further noticed that only one or two signals are placed on each post which greatly obviates the confusion occasioned by a great cluster or concentration of signals upon one post, or in one locality.

The great interlocking frame of 280 levers situated in the Large North Box already referred to, is of Messrs. Saxby & Farmer's latest pattern, including all their recent improvements.

This frame, with the preliminary spring catch rod actuation of the locking mechanism, by means of slotted rockers, cranks, and revolving gridiron plates, the latter engaging with locks or stops on horizontal reciprocating locking bars, has already received a detailed description in our June number, Plate CLIII., Figs. 247-8-9.

The facing point locks are of the above firm's usual and most successful type, *i.e.*, the combination of the plunger bolt, which enters a hole in the stretcher bar so as to secure the points in their proper position, with the parallel locking bar for preventing the operation of the points during the passage of a train. This lock has also been described in detail in our January number, Plate CXXXIII., Fig. 159.

The close proximity of all the points at the stations to the controlling box necessitates only short connections, which materially enhances the facility and safety of their operation.

The south cabin at the home or stop signals, already referred to, only communicates with the north box by means of mechanical visible signals, as previously mentioned, but the former, as likewise all the cabins down the line, communicate with each other as to the condition of their sections by means of Tyer's electrical block signalling instruments, assisted by the usual audible or bell codes.

In concluding our remarks on this terminus, we have only to add that the designing and execution of this extensive undertaking reflects the greatest credit on the Management and engineers concerned. And finally we should strongly recommend all engineers practically interested in the question of modern traffic management to avail themselves of an inspection of the actual work, which doubtlessly the Management would be pleased courteously to allow.

(*To be continued*).

CLEMINSON'S FLEXIBLE WHEELBASE.

FROM a pamphlet recently issued we extract the following particulars, showing the progress made by this invention:—

It is in operation on 150 railways—25 home, 95 foreign, and 30 Colonial and Indian lines. There are 26 engines and upwards of four thousand carriages and wagons running. There are also upwards of one hundred engines and two thousand carriages and wagons building. It has been graciously commended by His Royal Highness the Prince of Wales, and is applied to carriages of the Royal Family, the King of Italy, the Lieut.-Governor of the Punjaub, the Maharajah Scindia of Gwalior, the Rajah of Travancore, &c.

Comparative statement of weight and capacity of Cleminson stock, Bogie stock, and rigid axle 4-wheeled stock. Passenger stock.—North Wales narrow gauge railways, gauge 2 feet.—Bogie cars—Length 24 feet, capacity 28 passengers, weight $5\frac{1}{2}$ tons. Four-wheeled rigid axle cars—Length 12 feet, capacity 16 passengers, weight $2\frac{1}{2}$ tons. Cleminson's flexible wheelbase cars—Length 30 feet, capacity 42 passengers, weight $4\frac{1}{4}$ tons.

SUMMARY.—Compared with the Bogie cars the Cleminson cars seat 35 per cent. *more* passengers, whilst their weight is 25 per cent. *less*. To carry the same number of passengers as one Cleminson car, $2\frac{1}{2}$ four-wheeled rigid axle cars are needed, and as these last weigh $2\frac{1}{2}$ tons each, we have $2\frac{1}{2} \times 2\frac{1}{2} = 6\frac{1}{4}$ tons of dead weight, or 45 per cent. *more* than that of the Cleminson car. This fact illustrates very distinctly the economy resultant from increase of length of vehicle, when the English type of carriage is adhered to.

Ballymena and Larne Railway, gauge 3 feet.—Bogie cars—Length 35 feet, capacity 40 passengers, weight 9 tons. Cleminson cars—Length 35 feet, capacity 40 passengers, weight $5\frac{1}{2}$ tons.

SUMMARY.—In this instance, whilst the Cleminson cars have the *same* capacity as the Bogie cars, their weight is *less* by 35 per cent.

Manx Northern and Isle of Man Railways, gauge 3 feet.—Bogie cars—Length 30 feet, capacity 60 passengers, weight $9\frac{1}{2}$ tons. Cleminson cars—Length 30 feet, capacity 60 passengers, weight $5\frac{1}{2}$ tons.

SUMMARY.—With the same load capacity as the Bogie cars the Cleminson cars weigh 40 per cent. *less*.

Tasmanian Main Line Railway, gauge 3 feet 6 inches.—Ordinary 4-wheeled rigid axle cars—Length 18 feet, capacity 22 passengers, weight 5 tons. Cleminson cars—Length 36 feet, capacity 44 passengers, weight $7\frac{1}{2}$ tons.

SUMMARY.—The Cleminson cars carry each the *same load* as two 4-wheeled cars, with a dead weight of 25 per cent. *less*.

Midland and Highland Railways, gauge 4 feet $8\frac{1}{2}$ inches.

—Midland Bogie cars—Capacity 58 passengers, weight 24 tons. Highland Cleminson cars—Capacity 52 passengers, weight 12 tons.

SUMMARY.—With a capacity nearly equal to that of the Midland Bogie cars, the Cleminson cars weigh 50 per cent. *less*. Many other instances may be given showing the economy yielded by the Cleminson stock in point of dead weight in proportion to carrying capacity, in point of first cost, and, most important of all, in cost of haulage and repairs alike to rolling stock and the road.

Goods stock.—Uniao Mineira Railway (Brazil), metre gauge.—Bogie wagons—Length 25 feet, capacity 10 tons, weight $6\frac{1}{2}$ tons. Cleminson wagons—Length 25 feet, capacity 12 tons, weight 4 tons.

SUMMARY.—The Cleminson wagons carry 20 per cent. *greater load*, and weigh 30 per cent. *less* than the Bogie cars.

Paulista Railway (Brazil), gauge 5 feet 3 inches.—Four-wheeled wagons—Length 13 feet, capacity 8 tons, weight $4\frac{3}{4}$ tons. Bogie wagons—Length 26 feet, capacity 12 tons, weight 10 tons. Cleminson wagons—Length 26 feet, capacity 16 tons, weight $7\frac{1}{4}$ tons.

SUMMARY.—Compared with the Bogie wagons, the Cleminson wagons carry 25 per cent. *greater load*, and weigh 30 per cent. *less;* they also weigh 25 per cent. *less* than two four-wheeled wagons, whilst they carry an equal load.

EAMES' DUPLEX AUTOMATIC VACUUM BRAKE.

IN our last issue we described in outline the action of the Driver's Valve in its five different positions. There was then made mention of a small port in this valve not shown on the plates accompanying that description, which destroyed a vacuum over a small diaphragm, thereby starting the main ejector. On reference to Plate CLIX. Figs. 9, 8, 3, 10, this small port will be seen at *c*. The diaphragm alluded to is at *G*, Fig. 1. This port *c*, when the valve is in position *Rest*, is open to a small pipe *d*, connected at its other end to the upper side of diaphragm *G*, Fig. 1. This port, being of peculiar shape as shown, has its other end communicating with the Automatic Pipe *B*. For should the vacuum in Automatic Pipe be either accidentally or intentionally destroyed, the air admitted would find its way from the pipe *B* through port *c*, down pipe *d*, and so to upper side of diaphragm *G*, Fig. 1.

In Fig. 1 there will be noticed a valve and valve rod *e* and e^1. Below this is the steam way *f*, open to boiler pressure. Consequently, it will be observed that there will be steam pressure upwards against valve *e*, and so against outer end of lever *b*. This lever is pivotted at b^1. And again, when there is a vacuum above diaphragm *G*, atmospheric pressure below *G* will tend to force it upwards, and by means of stirrup *g* to draw the inner end of lever *b* up with it, in counteraction to the pressure of the steam at the other end. The vacuum does, in fact, more than counteract the steam. Therefore, on the destruction of this vacuum, it will now be seen, the steam will be able to pass this valve, and make its way to large ejector *H*, and so produce a vacuum in pipe A^1, Figs. 3, 4, connected at A^2 Fig. 1. On reference to Fig. 5, Plate CLVII., it will be observed that the driver's valve in this position of *Rest*, admits of communication through *E D* between *C* and *A*. Thus, by the action of the ejector, a vacuum being caused in the Plain Brake Pipe C^1 connected at *C*, the brakes will be applied. The admission of air into Automatic Pipe B^1 would also apply the brakes independently of ejector, as will be explained later on. A distinct difference in action between the two pipes B^1 and C^1 here appearing plainly, the admission of air in the former, and a vacuum in the latter, being required to make either apply the brakes. But under normal circumstances, the vacuum in the automatic parts remains constant. In the position *Rest*, if the brakes are on, they will remain on, or if off, they will remain off. To assume they are off, and it is required to put them on, the vacuum in the Automatic Pipe not having been interfered with, the valve is turned into position *On*, as shewn Fig. 6, Plate CLVII. To obtain the accuracy of position for the valve in either of these five positions, there are corresponding five notches in a quadrant *k*, Figs. 3, 4, and 7, behind the vertical handle by which the valve is actuated. Into these notches there drops spring catch *l*. The lower end of the catch having a large angle, it slides out and in of the notches on being forced over without requiring to be lifted; while at the same time it is quite sufficient to retain the handle in either of the positions in which it may be put, and so also to act as a guide in placing the handle correctly. When in position *On*, a small hole *r* in the valve, Figs. 9 and 10, is brought over the top of the pipe *d* (Fig. 3). This small hole, by means of passages *u* and *v*, Fig. 10, parallel with the axis of the valve, affords communication to the outer air at the back of the valve at *M*, Figs. 3, 4, 6, and 7. These passages are shewn by dotted lines in Fig. 8, and distinctly in sections on Plate CLVII. The result being that air is admitted to pipe *d*, and so to top of diaphragm *G*, thereby starting the large ejector *H* in the manner already described. And through the small passage *c* being closed, communication between *B* and *d* is cut off, and so a vacuum maintained in pipe B^1.

When the brake is put *Full On*, this little hole *r* still admits, by its lengthened shape, as will be seen at Fig. 9, Plate CLIX., of air getting into pipe *d*. But now,

in variance with the simple *On* position, the Automatic Pipe is brought into action. The release port *x* (Fig. 9, in communication with the open air through *u*, *v*, and *M*), being brought over port *B* as shewn in Fig. 7, Plate CLVII., destroys the vacuum in pipe B^1. Thus the Automatic Brake is applied—though independently of the ejector, as will be described later on. And the main ejector *H* being in operation through pipe C^1, and ports *C*, *E*, *D*, and *A*, the Plain Brake reinforces the Automatic.

The position *Off* is for releasing the brakes, when the automatic parts have not been called into requisition. The port *y*, in communication with open air through passages *u* and *v*, admits air into Plain Brake Pipe, and so releases the brakes. The small port *c* is over pipe *d*, and with its other end over port *B*, allows of communication, between the Automatic Pipe and the space above small diaphragm *G*. There being a vacuum in pipes B^1, the air is withdrawn from above *G*, and a vacuum being thus created, steam is shut off from ejector *H*, in the manner already described.

The position *Full Off* is assumed when the automatic parts have been used. The port *y* still admits air into Plain Brake Pipe, and communication is opened up between Automatic Pipe B^1 and large ejector, through *E*, *D*, and *A* (see Plate CLVII.). And the small port *s*, is brought over pipe *d*, admits air into it, and so starts the large ejector. Thus the ejector now withdraws the air from automatic pipes and reservoirs, restoring the vacuum much more speedily than were the work left to the small ejector alone. A convenience in connection with the driver's valve, is that the plug, catch-plate and quadrant, and handle, may all be withdrawn, by simply taking out the two small bolts at *m*, Figs. 4 and 5. A cap, open at the bottom, is fixed at the back of the valve at *M*, Figs. 3, 4, 6, and 7, through which the air passes into passages *u*, *v* of the valve when wanted. The spring *q* keeps the valve well up.

On Plate CLX. are shewn two views of the working parts as fixed beneath the carriage, one representing the brake *Off*, and the other *On*. There will be observed a *Duplex Valve Q*, and a *Cut Off* Valve *R*. This Duplex valve is illustrated at a larger scale on Plate CLIX., Figs. 11 and 12. *a* is the brake vacuum chamber closed by the elastic diaphragm *b*, carrying the metal discs *cc*, bolted together by a nut and bolt terminating in an eye *d*, to which the link working the brake lever is attached. *e* is one end of a vacuum vessel attached to each carriage and kept always exhausted by the same small ejector *I*, in operation continuously, which maintains the vacuum in the Automatic Pipe, which, with the Plain Pipe, runs the whole length of the train.

When the small ejector is started it exhausts the Automatic Pipe, and through the passage *p*, the chamber *f*, raising the elastic diaphragm and opening the valve *g*, through which, and the passage *h* the vessel *e* is also exhausted. Under the valve *g*, is a light spring, the use of which will subsequently be explained.

If now the vacuum in the Automatic Pipe be destroyed, the valve *g* will close, the diaphragm *f* will fall, and opening the valve *i* (which seats upwards), the air in *a* will be exhausted through the valve *l*, into the vessel *e*, and the atmospheric pressure forcing up the diaphragm *b*, will apply the brakes.

At the same time the large ejector is brought into action automatically (as described above) by the failure of the vacuum above its diaphragm, and as soon as the vacuum in the Plain Pipe exceeds that in the vessel *e*, the valve *m* will open, closing the valve *l*, and the vacuum in *a* will be maintained through the Plain Pipe. The brakes are released by admitting air to the Plain Pipe; and the vacuum being restored in the Automatic Pipe, the valve *k* is free to open, so that there is atmospheric pressure below *l*, as well as above *m*. Then the spring forces *l* up, and leaves *a* in communication with the atmosphere through the Plain Pipe. If both Automatic and Plain Pipes are broken and the brakes on, they can be released by opening the valve *n*. A small valve similar to *n* is also fixed on Automatic Pipe in Guards' van, so that by raising it he can apply the brakes should he wish. If the carriages are to be disconnected from the engine, the cock *q* is turned to maintain unimpaired the vacuum in the Automatic Pipe, and, in order that the brakes may not *leak on* by air getting into Automatic Pipe, the valve *g* is held slightly off its seat by the light spring beneath its stem. It is sufficiently open to let a small leakage through, but the complete opening of the Automatic Pipe will at once close it and apply the brakes.

In our last number it was described how that when this Brake was much mutilated, by diaphragms being cut, and so forth, yet the train was still held under perfect control. For on any diaphragm being destroyed, and in any way causing a leakage, the Automatic Brake will still work on all the perfect ones remaining in the train, that one alone being useless. As will be seen on reference to Plate CLX., on the vacuum in the Automatic Pipe being destroyed, the valve *g* closes, opening valve *i*: and valve *l* opens, closing valve *m*: communication being thus opened up between the damaged diaphragm and its own reservoir, but all connection with the Plain Brake Pipe, and through that to any other diaphragm, being cut off.

The elastic diaphragms have a great advantage over pistons, it is asserted, inasmuch as there is no rubbing friction, and no wear of packing. These diaphragms last over 200,000 stops on carriages, and on engines, where they are more quickly destroyed by heat and grease, over 90,000 stops.

The advantages claimed for this brake are summed up as follows:—

It is an AUTOMATIC vacuum brake. It is a PLAIN vacuum brake. It is an AUTOMATIC and PLAIN brake combined. It is the most efficient AUTOMATIC brake in the world. It is the most efficient PLAIN brake in the world. It is the only AUTOMATIC and PLAIN brake combined. It is perfectly simple. It is easily maintained. From its peculiar form, it is perfectly elastic in action, which commends it par-

ticularly to the travelling public in making easy stops. Its elasticity prevents the harsh usage of brake gear and blocks, thereby ensuring greater security, as well as a considerable saving in wear and tear. It is the most economical in the use of steam to maintain its automatic power. It is attached to the engine at a less expense than other automatic brakes. Carriages fitted with ANY plain vacuum brake can be attached to an EAMES train, and the brake still be continuous throughout the whole train, and will be automatic as well, only with less automatic power; depending upon the relative number of plain and automatic carriages. Eames carriages can be worked by engines fitted with ANY plain vacuum brake as a plain vacuum brake train. Carriages fitted with ANY automatic vacuum brake may be attached to an Eames train, and the brake still be continuous throughout the train, also automatic throughout. Eames carriages may be worked by engines fitted with ANY automatic vacuum brake, with but a slight addition to the engine attachments. The Eames can be attached to carriages fitted with any plain vacuum brake, and utilize in most cases the entire plain equipment, and in NO case discard more than the hose couplings. The locomotive fittings of any plain vacuum brake can be utilized to convert into the Eames Duplex Automatic, thus making no inconsiderable saving in outlay. It is the only brake that can be used as a simple plain brake, for making station stops, and running down long inclines, and at the same time maintain in PERFECT EFFICIENCY its automatic feature. It is the only brake, of those deriving their automatic power from the locomotive, which, from the failure of the parts utilizing power, applies itself, that can be released from the foot plate of the locomotive by the driver without delay, and though no longer automatic the train is still equipped with a first-class continuous plain vacuum brake.

THE EXHIBITION OF LIFE SAVING APPARATUS.

The proceedings of the Exhibition of Means and Appliances for the Preservation of Human Life reached their culminating point on Saturday last, when the awards of the jurors were distributed to the successful exhibitors by H.S.H. the Duke of Teck, supported by his Highness the Rajah of Rampur, and Mr. Burdett-Coutts, in the presence of a vast and distinguished assemblage. It is satisfactory to know that amongst the many and varied appliances gathered together in the great hall of the Alexandra Palace, the railway interest was worthily represented; that a large amount of business was done, and the way paved for a great deal more. The management at the Alexandra Palace was far from satisfactory, and the Exhibits a nd Ctalogue seemed to be arranged without any intelligible plan. Nevertheless, the collection itself was of so high an order as to warrant the belief that the next gathering ot the kind will lead to increased success. The Railway appliances were of the highest merit, and secured the commendation of hundreds of eminent critics, while the Exhibition as a whole, judging from the interest manifested in it by thousands of the general public, must have been of service in an educational sense by imparting some comprehension of the vast forces of machinery to many a hitherto uninstructed mind.

Messrs. Saxby and Farmer exhibited 1. Union of the Block and Interlocking Systems and Electric Slot Signal.—Adopted by the London, Brighton and South Coast Railway Co.; now in use on the Tunbridge Wells and Eastbourne Line, and approved by Colonel Yolland, R.E., Government Inspector of Railways.—This full-size exhibit, illustrating these inventions, consists of an interlocking apparatus of seven levers for working points and signals, and telegraphic block signalling instruments for the exchange of train telegraph signals with stations on either side, for up and down lines respectively, and also a lever fitted with the "Electric Slot" arrangement. The block telegraph instruments and the point and signal levers being combined in one and the same interlocking arrangement, so that they cannot be manipulated in a contradictory manner. It should be observed that the out-door starting signal cannot be given to permit entrance into a block section without the consent and concurrent action of the signalmen at both ends of such block section, and by means of the "Electric Slot," the out-door signal at one station can be instantaneously changed from the "Safety" to the "Danger" attitude from any other station, irrespective of distance. The instruments exhibited are constructed on the one wire system, *i.e.*, one wire only being required for the transmission of the block telegraph signals and the actuation of the bells for such up and down traffic.—Gold medal.

2. Patent Facing Point Lock.—The exhibit is a full size set of facing points, provided with the "Duplex Lock or Detector" according to Mr. Farmer's patent. This invention is designed to meet the possible contingency of the breakage of a connecting rod between a set of points, and the locking apparatus in the signalman's cabin, which mishap would permit of the point lever being placed in its intended proper position to change the direction of the points, and to unlock the signal which, in the changed position of the points, it would be safe to give; but owing to the connecting rod being broken the points would have remained unmoved, and would actually be standing in a contrary direction to that which the signal would indicate.

3. Model of Annett's Patent Safety Lock for Outlying

Sidings.—This invention is designed to extend the security of the Interlocking System to outlying points too far from a station signal box to be worked and interlocked with the signals in the ordinary manner. For this purpose a key is provided of special design, and of which no duplicate is made, and which fits two "Duplicate Safety Locks," the one connected with the outlying points, and the other with the signal levers in the station box, and is so contrived that after being used in either lock it cannot be got out again without locking the points or the signals, as the case may be, in the proper position to ensure safety.

4. A Large Model of a Railway Junction illustrating the harmonious working of:—Interlocked points and signals, with patent facing point lock, and level crossing gates interlocked with the signals. This valuable combination insures the safe working of railway traffic over public roads, and of public road traffic over railways, at level crossings. The gates cannot be opened for road traffic without the railway signals being first set and securely locked at "danger," and the railway signals cannot be given to allow trains to pass until the gates have been first closed and securely locked against the high road.

5. A diagram model showing an economical arrangement for controlling the opening of Level Crossing Gates from a distant signal box and interlocked with the signals thereat.

Mr. Cheesewright exhibits Sykes's combined lock and block system of railway signalling, which the inventor claims to supply the missing link between the lock and the block, rendering it impossible for a signalman to admit two trains following each other into one section of the line at the same time, or to pass a train while the points are open for the performance of a shunt. The shunt cannot be made if "line clear" has been given for a train to advance, until that train has passed clear out of the station, everything being done by levers, so that there cannot possibly be any mistake. The operation is shown in action at the Exhibition, and is clear even to the uninitiated, while the opinion of the signalmen who have worked practically with it is that they would not go on a line that did not possess it.—Gold Medal.

Mr. Arthur Kelday showed an Electric Fog Signal which does away with the use of Fog Signalmen, and also the Detonator; it gives the power to the man in the signal box to give warning to the driver of the approaching train by turning on the whistle, and also gives the signalman power to stop the approaching train by turning off the steam and putting on the brakes.

The Midland Railway exhibited an Interlocking Signal Lever frame and Facing Point Lock, and Mr. J. P. Knight, of the London, Brighton and South Coast Railway, Annett's appliances for extending the interlocking system to outlying points (Silver medal); Stroudley's communicators between passengers and guard and electric block signalling instruments. Mr. C. H. Lea had a working model of Safety Railway Crossing Gates, interlocked with home and distant signals, and special arrangements for fog signals in case of accident, or when the signals cannot be seen in foggy weather. Working model shewing apparatus for placing fog signals consecutively on the rails of railways at any distance from pointsman's cabin. Also self-acting appliance to communicate to man in cabin. Working model shewing apparatus for securing the safety of markers at rifle ranges. Also special arrangements for firing parties to communicate with marker. (Silver Medal.)

Mr. S. A. Say showed a Patent Fog Signal appliance, the object of which is to do away with the dangerous practice of laying fog signals by hand.

Mr. S. Sealy Allin claims for his invention, that it provides an automatic and infallible counteraction of the variations in length of the wires connecting the semaphores with the levers in signal boxes, and removes the serious dangers caused by such variations, and the consequent irregular action of the semaphores. Its principle is simply to establish a balance on the rock lever at the foot of the Semaphore Post by making the expansion of the wire cord attached to one arm, and of the rod connecting the other with semaphore arm to counteract each other, and this it does by making the rod connecting with the semaphore of zinc instead of iron, zinc having just three times the expansive and contractile power of iron, and by making the lever of such proportions that the low expansion of a long length of iron wire on the long arm shall be balanced by the high expansion of a short length of zinc on the shorter arm. It is the easier to do this, as in practice it is found that in consequence of the weight of the wire and the friction at its supports, a certain percentage of its expansion never reaches the semaphore, from 20 per cent. on a short and straight line, to 40 per cent. on a long and curved one, being thus lost, and only manifesting itself by the greater flexibility and easier tension of the cord. This fact practically increases the relative expansion of the zinc rod to that of the wire cord by one-third, making it in effect four times that of the wire, so that the expansion of a 45 foot rod of zinc attached to an arm of one-and-a-half inches will balance that of an iron wire 800 yards long attached to an arm 20 inches, when the lever moves each arm will describe an equal arc of a circle. As the wire cord expands, the weight on the other end of the rock-lever descends, causing the arm to which the cord is attached to rise, while the short arm to which the zinc rod is attached, descends, the zinc expanding, and following it down leaving the semaphore arm in an unchanged position.

Mr. F. W. Dalton's model of an apparatus for fixing on railway carriages to prevent them from telescoping into each other, attracted considerable attention.

The invention of Mr. J. Holden is designed to remedy the defects that now exist in the wooden key or wedge used in retaining the rail in position in the chair of the permanent way. The key or wedge, when driven home between the jaw of the chair and side of the rail, for the purpose of securing it, swells or expands in damp weather, and shrinks in dry

weather, when the ordinary key becomes loose and liable to fall from position in the chair, to the great danger of the rail shifting. This invention consists in forming a longitudinal groove in the surface of the key next to the jaw of the chair, and interposing between the jaw and the key, a bow spring, the body of which fits in the groove of the key, while its ends are bent to embrace the ends of the jaw, thereby preventing the spring from becoming displaced longitudinally; while its force bears continually against the key, however much the latter may shrink, thus keeping the same firm in its position.

Mr. Barrow has a Patent Fog Signal Apparatus for preventing collisions when shunting in fogs, tunnels, and underground railways, junctions, facing points, and level crossings. Also one for the protection of platelayers and fogmen. The apparatus is placed on a sleeper with two fog signals 150 or 200 yards from where the platelayers are working, a cord is attached to a reel and thrown down where they are at work. If they see a train coming they pull the cord tight and the fog signals are taken off when the train is passed; by slackening the cord the fog signals return to their normal position. By reversing the cord from right to left they will answer equally for fogmen. That for underground railways is to place an apparatus every 100 yards distance from each other. If a train breaks down or stops in a tunnel all they have to do is to pull the wire and all the fog signals go on for at least eight or nine hundred yards. The other is placed at the distant signal ten yards apart, and is worked from the cabin by a compensating wheel. A lamp is fixed outside the cabin with a slide that moves up and down, so that anyone on the platform can see if the signalman has protected the trains or not; if not, they can ring a bell which is fixed in the cabin.

The stand of Messrs. Brear and Hudson contained Electrical Railway Signals and Signal Repeaters. By this method signals can be worked in much less time and far more easily than by levers: also it takes a great deal of responsibility off signalmen, as he in the cabin lowers a signal by electricity with connection for the train to approach (line being clear); his responsibility is taken away as regards pulling the signal back to danger, as there is an arrangement on the rail or rails to pull the signal back to danger by the weight of the engine passing over a lever a few yards past the signal post, and the pointsman can tell exactly when the train has passed the distance or other signals, as the before-mentioned Signal Repeaters in the cabin fly to danger as the train operates the signal to danger by the arrangement on the line, and blocks the line for the next train, which in due course is lowered by the electrical arrangement with a switch by the signalman or pointsman in the cabin. There can be no fear of the pointsman forgetting to put the semaphore back to danger, as the train while passing on the line operates the signal to danger, which always blocks the next train to come. In case of emergency on the line, or if the signalman lowers a signal in mistake, he is enabled by connection independent of the mechanical arrangement on the line, to send an extra force of electricity from the cabin, which will operate the signal back to danger through powerful electro-magnets placed at the bottom of the post, which, while attracting, works the semaphore to danger.

Mr. E. A. Sullivan aims at providing means calculated to conduce to greater safety in railway travelling by means of his Patent Electric Fog and Night Signal, as shown by model. A strong wrought-iron bar is pivoted to the side of the rail, which acts as the armature of a powerful magnet, and to the end of this bar a lever or striking hammer is jointed, and the end of the bar which is connected is made to project slightly over the rail, being held in place by a spring. When the ordinary semaphore signal is at "danger," the wheels of a passing train strike this bar, the depression of which causes a powerful gong to sound, warning the driver and notifying him to stop before reaching the point of danger. When the ordinary signal is made to indicate "all clear," the signalman, in pulling over the lever, actuates an arrangement attached thereto, by means of which an electric current is conveyed to the magnets, and the bar is again depressed below the level of the rail, no sound is then emitted by the gong, so that passing drivers know that the visible signals are clear for them to proceed. If necessary, this apparatus can be actuated from the signal-box by wire rope in the customary way. The great value of Mr. Sullivan's invention will be most apparent in foggy weather, when the driver of a train can scarcely see, if at all, the arms and lights of the semaphore.

The use of the Douglass coupling has been so very successful and satisfactory on the London and North-Western, that they are now being put on at the rate of 800 per month. The Lancashire and Yorkshire Railway Company are also endeavouring to diminish the responsibilities incurred by so many accidents, by an extensive trial of them, 500 sets having been put into use on their line, and the Midland Railway Company, after mature consideration, have ordered 100 sets to be fitted to 100 new wagons for a thorough trial. Several other railway companies have also expressed their approval of the invention, and are only waiting a revival of trade to adopt it. These couplings were described in the *Railway Engineer* for May, 1881.

Bezer's Patent Lock Nut Company's invention is a mechanical instead of a frictional one, forming a very neat as well as secure fastening. It can be taken off and replaced at will without injury. Messrs. Peters & Co. showed a multitude of invaluable appliances for the safety and comfort of railway travellers.

The Heberlein Brake Company exhibited their important apparatus, which was fully described in the *Railway Engineer* for July, 1881. (Bronze Medal.) Mr. W. T. Elliott had two railway signals, and Mr. Jacomb, London and South-

Western Railway, Preece's Patent Electric Block Signal Instruments. Mr. J. B. Fondu's improvements in locks and fastenings for railway carriages are of a practical character (Bronze Medal), as also are the improvements in doors of Mr. Greenwood. Mr. John Bateman's models are of world-wide celebrity, those of a six-coupled Midland goods engine and a Great Northern locomotive express engine being splendid specimens. Mr. W. Parker-Smith's brake and appliances were described in our pages in May, 1881. (Bronze Medal.) Mr. Hornsby, of the Midland Great Western Railway of Ireland, showed a set of six train staff boxes, with brass train staffs—round, square, and triangular—also train tickets—red, white, and blue. These illustrate the working of a single line of railway (divided into three sections) by means of the train staff system. No train is allowed to leave a station unless the train staff of the section is at the station. If more than one train is required to run in the same direction in succession, one of the train tickets is given to each of the trains, except the last train, which carries the staff, and until the staff reaches the other end of the section no train can be started from that end to run in the opposite direction. The train tickets are kept locked up in the boxes, and the train staff itself is the key which unlocks the box. The Midland Great Western Railway of Ireland has a total mileage of 425 miles, of which 76 miles (being single line) are worked by the train staff system. On some of the branches this system is supplemented by the telegraph, and a form of "line clear" ticket to accompany each train is also exhibited. On other portions the train staff and block telegraph are combined.

Messrs. Garnham & Co. exhibited railway electric specialities, including Harper's improved arrangements of block signalling instruments. (Bronze Medal.)

Mr. J. Harrisson showed his patent automatic disjunctive and self-adjusting apparatus for interlocking, and other railway signals.

The Great Eastern Railway Company had a buffer stop (Langley's Pattern), the object of which is to prevent the severe shock which a train would receive when running at a high rate of speed into a terminus or siding (the brakes failing to act through being out of order, or other causes) and coming violently into collision with the dead or spring buffer usually placed for the purpose. It also prevents the recoil which so often causes more damage than the collision. (Bronze Medal.)

Lancashire and Yorkshire Railway (Warburton) exhibted electric block signalling instruments and relays, &c., of the most recent descriptions.

Messrs. R. Rogers & Co. had one full size model of Mawlams' Patent Truck Couples, applied to connecting chains of railway trucks.

Mr. W. T. Whiteman's automatic check system of railway signalling consists in the employment of automatic signalling apparatus, working independently of the ordinary handworked semaphores, and acting as a check on the signals given by the latter. The apparatus is electrical and works on the block system, and the state of the line, whether clear or blocked, is unerringly indicated to the engine drivers, by the display of one or other of two differently coloured discs on the weather board of each engine, and immediately before the driver's eyes. A working model may be seen in London by appointment with above.

Mr. G. R. Kittridge showed a rough model of an invention for preventing accidents on railways through passing signals set at danger, by automatically shutting off steam, sounding an extra whistle, and setting on the brake. Five years ago this was submitted to the then manager of the North London Railway, who acknowledged its utility for the purpose designed. It is very simple and inexpensive, using existing signal apparatus, and could be gradually developed on any line of railway, as it could be applied to any particular signal and any special engine without interfering with others as at present used.

F. W. Eames (Eames' Brake Co.).—Patent Duplex Automatic Vacuum Brake, and great locomotive from Balwin's Locomotive Works, Philadelphia, U.S.A. This Brake was described by us last month. The great locomotive the "Lovett Eames" was an object of much interest and admiration. Being too huge for admission to the Palace, it was shown in the north grounds. (Silver Medal.)

Mr. T. A. Brockelbank had three large railway wagons illustrating the action of his Automatic Couplings, and present method of chain couplings between vehicles. The couplings are saving of life and limb of railway servants, and time and money in traffic expenses. Also a railway tram of large models (25 ft. by 3 ft.) a locomotive brake van, and three wagons, shewing the connections of automatic couplings—tightening, loosening, and releasing in one action—and wagon disengaging levers, insuring immunity from accidents to shunters, and despatch of traffic.

Mr. J. White's improvements in railway signalling, relating more especially to fog, will be fully described in an early number.

Messrs. Warner, Walduck, and Davies laid down 60 ft. of railway permanent way secured by Mathews' patent iron chair and eccentric block, ensuring dispatch in laying and removing rails and safety to the servants employed, and to passengers, from the fact that the eccentric block is so designed that it does not get loose or fall out like an ordinary key. This invention consists of a cast-iron chair and an eccentric block or key, also made of cast-iron instead of wood, as usual. The key forms, with the joint of the chair, a horizontal revolving joint, which allows the outer edge of the key to fall as it wears, so that its pressure upon the rail is constantly maintained in an unvarying line between the rail and the chair. The key is so made that it cannot slip out of the chair endwise; and it can be placed in position after the rail is laid, or if the rail be slightly tilted the

whole of the keys required for its length can be adjusted at one operation. Great safety is insured by the fact that when the key is placed in position, it will not get loose, nor will it fall out like an ordinary wooden key; and, as its weight causes it to drop against the side of the rail, it automatically adjusts itself as the surfaces of the chair and rail in contact became worn.

Messrs. Lethullier and Pinel, of Rouen, exhibited a magnetic indicator for avoiding accidents to engines and steam boilers, by establishing a communication between the interior and exterior of the boiler through a copper plate. A spheroid tested to 15 atmospheres forms the float. It is surmounted by a powerful magnet, which works smoothly in a square copper casting, following the variation of the level of water. On the exterior, and against one of the faces, is a needle deprived of all mechanical support, only maintained by the attraction of the magnet, and travelling through the divisions of a graduated scale, the cipher of which corresponds to the normal level of the water in the boiler. The height of the level of the water is always in view, as the needle follows all its fluctuations. The extreme limits of the course of the needle cannot be attained without the pin on the rod touching the lever of the whistle, so by warning that high and low water is attained as indicated by the apparatus. The weight of the float and magnet preventing their being suspended in vacancy, makes them infallibly work with accuracy.

A NEW AUTHORITY ON CONTINUOUS BRAKES.*

Mr. Reynolds explains that his purpose in writing this book has been to contribute his quota of experience "for the diffusion of knowledge and the prevention of accidents." Mr. D. K. Clark, who revised the text, seems rather to think his friend has succeeded, and observes that the latter's "judicious criticism, tempered by experience, must prove valuable to all who desire to understand the subject." Mr. Reynolds's experience we do not question, but the criticism which, by some occult process, it is supposed to "temper," is anything but judicious. It will neither convince nor interest. Mr. Reynolds poses as the instructor of mankind on a subject which is still one of controversy amongst the very best informed, and the reader gets to the end of the preliminary matter with his mind already mildly excited to wonder as to why Mr. Reynolds, who has written some really useful little books, if he was irresistibly seized with the *cacoethes scribendi*, should have chosen, of all subjects, that of continuous brakes, only to inform the world that all existing apparatus of the kind is of the most useless and dangerous character. Save one!

The value of the chapter on "Early Brakes" may be gathered from the fact that the author advances, presumably as something novel, that "friction is the resistance experienced when one body is rubbed upon another body," while, in "Conditions of a Perfect Brake," the clearest intellect will fail to discover anything much younger than the hills. Pursuing his career "for the diffusion of knowledge," Mr. Reynolds next informs us that many of the conditions required of a good brake are not fulfilled in the continuous screw brake. "The conditions which have been formulated for a good system of brake are not to be found in the chain-brake," while Clark's "has the great defects of all chain-brakes." Being now well started on his iconoclastic course, the author proceeds to demolish, first, Smith's Vacuum Brake as powerless in most cases where it is likely to be required; then Hardy's Vacuum Brake as "very imperfect and unfit for practical use;" to Steel and McInnes' Compressed Air-Brake there are three objections, "owing to which it has never been introduced largely into practical use;" the Eames Brake does not give any more security than a Non-automatic Vacuum Brake;" Aspinall's Automatic Vacuum Brake "is subject to most of the objections raised against the Hardy Brake, so far as the single pipe brake is concerned; whilst the Double-pipe Brake has the same defects as the Eames' Brake;" the Baxter Hydraulic Continuous Brake is unreliable owing to the use of water pressure as its motor; the Clayton Brake is greatly complicated, and its leak-hole arrangement is an "utterly unsafe and bad contrivance."

Having reached this point, the reader will probably have arrived at the conclusion that the upshot of Mr. Reynolds's "diffusion of knowledge" will be to convince everyone that no form of brake is possible on earth, and that "the prevention of accidents" is only to be achieved by abolishing railway travelling altogether. But turning another leaf he discovers the key of the whole position—the name of Westinghouse, about whose brake Mr. Reynolds says "it is impossible to come to any other conclusion than that the system invented and perfected by Mr. Westinghouse is the one that meets entirely all the requirements of the Board of Trade." There is one person at least who may be supposed to know as much about those requirements as Mr. Reynolds, and that is Colonel Yolland, who has given his opinion of the capacity of the Westinghouse brake in no uncertain language.

When Job made his celebrated observation, "Oh! that

* Continuous Railway Brakes. By Michael Reynolds. London, Crosby Lockwood & Co., 1882.

mine enemy had written a book," he must have wished that the book was one like this. It starts with the announcement of a purpose which it utterly fails to fulfil; it provides no information which the specifications do not give in a clearer and better form; its style is repulsively didactic, and in cases impertinent to the verge of vulgarity. "There can be no question," observes Mr. Reynolds, "about the Stephensons having heads like a carpenter's shop." The "Stephensons" might be prepared to reply that other people's heads sometimes resembled the material most manipulated in carpenters' shops. "There is no doubt," says Mr. Reynolds (who is never "in doubt," and about whose utterances there never can be "any question"), "that we are even now going to work in an odd sort of fashion." Indeed we are, if Mr. Reynolds is to be recognized as the exemplar of the "we" in question. It is an "odd sort of fashion" to produce a book abusing every species of invention for the glorification of a contrivance which has been condemned by competent authority on the ground of its own repeated failure.

OFFICIAL REPORTS ON RECENT ACCIDENTS.

Major Marindin has reported the result of his inquiry into the causes of a collision which occurred on the 13th May last, at London Road station on the Manchester, Sheffield and Lincolnshire Railway. From the evidence it appears that the present practice is for trains leaving London Road station to start by signal from the guard, who receives the necessary permission from the inspector in charge of the platform. When it has started it proceeds towards the junction signal-cabin, either upon the main line or upon the middle line, at the discretion of the foreman shunter, who is solely responsible for the line upon which a train is to run on entering or leaving a station. There is a little discrepancy in the evidence on this point, but it seems pretty clear that when running out upon the main line the driver receives no further signal until he arrives at the starting signal worked from the junction cabin, which signal is far beyond the facing-points, and is for the protection of the junction only; unless there is some obstruction, when he is brought to a stand by a hand-signal from the foreman shunter or his assistant, standing at or near the end of the platform, about 110 yards from the point from which the train starts. If, however, the main line is not clear the train is turned on to the middle line through a set of facing-points about 55 yards from the starting point, and in this case the driver receives a hand-signal from the man holding the points, and is, as when running in the main line, stopped if necessary by the foreman shunter or assistant, if the middle line is obstructed beyond the end of the station. It is stated that the train should not be turned on to the middle line without authority from the foreman shunter, or shunter in charge, but it is quite clear that this is often done, although the evidence of the regular shunter proves that in such cases, when he has done it on his own responsibility, he has been reprimanded by the foreman. Upon the night in question the foreman shunter was on duty, and intended to send the train out on the main line, but a porter, Gardiner, who was acting in his turn as assistant shunter, took it upon himself, without any orders from the foreman, to turn the train on to the middle line, although from the position where he was, when holding the points, it was impossible for him to see whether this line was clear for any considerable distance. This man excuses himself by stating that he had done the same thing on four previous nights in the same week, without being checked for it, and that when he went back to the points the middle line was clear, and the main line was obstructed. He is contradicted by the foreman, and, inferentially, by the regular assistant shunter, who states that the foreman has always checked him when he has so acted without orders, and I must therefore throw all the blame upon the assistant shunter Gardiner. Nevertheless the collision was due more to the defective arrangements in this station than to the fault of any particular servant in carrying out the work. The practice of starting trains by hand-signal given by a man, the platform inspector, who knows nothing whatever about the state of the lines beyond the platform, and who is actually ignorant as to which of two lines the train is to run upon, is radically wrong, for drivers do not get any positive signal that the line upon which they are running is unobstructed, as they do when a properly placed fixed signal is lowered for them, but only a signal when the line is obstructed, which, as in this case, is liable to be given too late. I am glad to learn that the re-signalling of this station is likely soon to be carried out, and that there will then be no points worked from the ground and unprotected by signal, but in the meantime I think that the regulations for working should be altered, and that trains should never start until the driver receives a signal from the foreman shunter or the person responsible for the condition of the line. The driver of the mail train is not in any respect to blame, but it should be pointed out to the foreman shunter that, if he had done his duty properly, and had not contented himself with simply reprimanding his subordinate for repeatedly acting upon his own responsibility, in contravention of orders, the porter acting as assistant shunter would probably not have followed the bad example of the regular shunter, and this collision would probably not have occurred.

Major-General Hutchinson has reported the result of his inquiry into the circumstances connected with the accident which occurred on the 17th May last, between Bow signal-cabin and Coborn Road station, on the Great Eastern Railway. Judging from the evidence, and from an examination of the permanent way, and of the train which met with the accident, there appears to be but little doubt that the accident (after the occurrence of which the train ran about 700 yards) was due to something faulty in the permanent way where the rail of a cross-over road crosses the main rail of the up line close to Bow signal-cabin. In the train, which consisted of an engine and nine vehicles, running at the time at a speed of about 25 miles an hour, there were marks on the outside of the right wheels of the fourth, fifth, sixth, and seventh vehicles; the right middle wheel of the eighth vehicle was displaced, its journal having managed to force itself from between the jaws of the hornplate, and when the train stopped, this journal was found resting on the foot-step, and pressing against the rear hanger; the last vehicle was off the rails with all six wheels, the right wheels being in the four-ft. space, about eight or nine inches from the inner rail. The first mark on the line of a vehicle being off the rails was at a chair securing the inner rail, six feet beyond the angle of the crossing. This chair was broken, and then a number of chairs were marked or broken, and wheel marks soon appeared in the ballast. From the evidence of two platelayers (the ganger had been dismissed, and did not attend the inquiry) it seems that shortly before the train had passed a new chair in place of the former one, which had been found to be broken across the sole, had been put in at the crossing of the rail of the cross-over road with the main rail of the up line. This new chair is said to have been properly secured before the train passed, and the ganger appears to have asked the signalman to keep up his signals during the operation of changing the chairs. However this may be, there appears to have been want of due care in properly securing the new chair (supposing it, as stated, to have been substituted for the old broken one), and the gauge at this point was consequently enabled to be spread by the passage of the engine and first three vehicles of the train, the four next vehicles then seem to have partially left the rails with their right wheels, but to have recovered themselves; the right middle wheel of the eighth vehicle must then have received a severe blow, probably at the point of the crossing, by which the axle-box was broken and the journal forced back behind the hornplate; and the ninth vehicle left the rail with all its wheels. The gauge appears to have been correct, and the wing rail though worn not to have been in a dangerous condition. The rolling stock composing the train was nearly new, the tyres but slightly worn, and the gauge correct. The accident is therefore, I think to be attributed to the ganger having neglected his duty in not having seen, when executing necessary repairs at the crossing in question, that the line was in a safe condition before allowing trains to pass over it at speed. A consequence of this accident was the fracture of the brake truss-rods (of 1 in. round iron) connecting the brake-cylinders with the brake-blocks of the rear carriage, these blocks thus becoming useless; this occurred from the truss rods coming in contact with the axles when the carriage had left the rails. This was of no consequence in this particular case as the air-brake was not in operation on the train, the engine not having been fitted with the necessary appliances. But it might under many circumstances become a very serious matter for the brakes on vehicles to become inoperative in the case of a train leaving the rails, in consequence of the brake truss-rods becoming damaged. Attention should, I therefore submit, be directed to arranging the position of brake truss-rods (and, perhaps, to making them of a stronger section), so that their liability to be broken in case of a run-off shall be as small as possible. The make-up of the train in this case was by no means a proper one, there having been nine vehicles with the only available brake power in the vehicle next the engine. As it was, no serious results ensued from the absence of brake power at the tail of the train, though it might well have been otherwise. Had the brake with which the vehicles of the train were fitted been in operation, and had there been (as there should have been) a guard in a rear brake-compartment having the power of applying the brakes, the perilous journey of 700 yards, which was run by the last vehicle with its wheels off the rails, might have been considerably reduced.

Major Marindin has also reported the result of his inquiry into the causes of a collision which occurred on the 29th May last, at Farringdon Street station, on the Metropolitan Railway. If the evidence of the driver of the Great Northern train could be accepted as correct, the cause of this collision would appear to have been the accidental failure of part of the mechanism for applying the continuous brake with which the train was fitted, but even in that case I do not consider that the driver would have been altogether free from blame. According to his own statement, he applied, or tried to apply, his continuous brake, when running at a speed of about 8 miles an hour, at a point nearly 200 yards from the signal at which he ought to have stopped, and 293 yards from the point of collision, and only found out that it would not act when he was about 60 yards from the signal and 156 yards from the point of collision. He says that he then reversed his engine and applied back steam, and that his fireman sanded the rails and applied the tender-brake; but he did not sound his whistle for the guards' brakes, as he should have done. There would have been time to stop the train with the hand-brakes if they had been applied at the place pointed out by the driver, unless the speed was far higher than it is stated to have been. His statement that he was stopped at Smithfield junction signals

for two minutes is categorically denied by the signalman in Smithfield junction signal-box and by the guards of his own train, while it is hardly substantiated by the prevaricatory manner in which his fireman gave his evidence on this point. The signalman in C signal-box, Farringdon Street, by his evidence given very clearly and positively, also contradicts the statement of the driver; for he declares that steam was off when the engine passed his signal-box, in which case no back steam can have been applied, that the rails were not sanded until the engine had passed his signal-box, and that the fireman did not apply the tender-brake until he saw him signalling from his window. Taking all the evidence into consideration, I cannot avoid the suspicion that the driver was not keeping a proper look-out, did not see the signals against him, and did not take steps to stop his train until close to C box, when he got flurried and did not make use of his vacuum-brake; and further that, in order to excuse himself, he invented the story about the dropping out of the pin, which appears, not only to myself, but to the officers of the locomotive department of the Company, to have been most improbable. This driver is an old servant of most excellent character, and if his statement in other respects had not been proved to be untrue, I would not suspect him of such misconduct, while I would be very glad if my suspicions could be proved to be unfounded. A more important point to which attention should be called is the inadequate provision for safety which is afforded by the regulations for block working at this junction, where "line clear" is allowed to be given to the block post in rear before the preceding train has started from the platform and is proceeding upon its journey, and also where two trains are allowed to approach a junction upon converging lines at one and the same time. In the first case the margin of safety is only the distance of 96 yards between the home-signal and the platform, and in the latter case it is still less, being only the distance between the home-signal and the fouling point of the converging lines; and when trains fitted with continous brakes are permitted to run up to the home or junction signals at high rates of speed, trusting to their continous brakes to pull them up, it is evident that any failure may cause a very serious accident. No system of block working can be considered satisfactory in which the safety depends upon the proper observance of one signal, and the certainty of action of a continous brake, which, like every machine, must be liable at some time or another to fail; and I hope that the Metropolitan Railway Company will decide to adopt similar regulations to those in force upon some other lines, where it has been found quite practicable to work the traffic under the conditions of trains not being allowed to leave one block post until the preceding train has passed the block post ahead and is proceeding upon its journey, and of two trains not being allowed to approach a junction upon converging lines at the same time.

Colonel Rich has reported the result of his inquiry into the circumstances which attended the accident that occurred on the 29th May last, near Whittington Station, on the Cambrian Railway. No passengers were injured. The accident was caused by attaching the shunting-engine to the tail of the 8 a.m. passenger train from Aberystwith. This engine is of a description which is quite unfit to run safely with any train. It was attached to the tail of the train by the orders of the station-master at Oswestry, who had directed the yard shunting-engine to assist trains up the Frankton bank on previous occasions, and he was not aware at the time that No. 2 shunting-engine was a different class of engine to the shunting-engine which he had sent away on previous occasions. The driver of this engine seems to have demurred to go with the train, as his fireman was absent, when he was ordered to do so by the yard foreman, who conveyed the station-master's orders; buthe went as soon as a fireman was provided for him, without making any objection on the score of his engine being unsuited or unsafe for such work. This man should have objected to go on the plea that his engine was unfit for the work, and both the engine-driver and the station-master ought to have consulted the locomotive foreman, who was on the platform at the time, before the shunting-engine left the station. The locomotive foreman was not aware that this engine was to be sent away with the train. He stated that he would not have allowed it to go if he had known it. The station-master at Oswestry is mainly to blame for the accident. The driver of No 2 engine stated that he shut off steam immediately after leaving Oswestry, and that his engine was pulled along by the passenger train down the incline towards Whittington. While following the train, which ran at high speed, it must have bobbed up and down very much, owing to its having only four wheels and a very short wheel base, and on reaching the two underbridges near Whittington Station, wooden platforms would yield under its weight. The front end must first have gone down whilst on the first bridge, and then have been lifted up as it ran over the stone abutments and 20 feet of intervening ballast, and have jumped off the rails as it passed over the second bridge. It left the rails about the centre of the second bridge.

Major Marindin has also reported the result of his inquiry into the causes of a collision which occurred on the 5th June last, at Macclesfield Central station, the joint property of the North Staffordshire and Manchester, Sheffield, and Lincolnshire Railway Companies. From the evidence it appears that at 8.45 a.m. the 7.45 a.m. Manchester, Sheffield, and Lincolnshire train from Manchester arrived from Macclesfield, off the Manchester, Bollington, and Macclesfield branch, and that, after the passengers had been discharged at the up platform, the engine, as usual, ran round the train, and backed it along the up line until it

had passed beyond the south cross-over road. Here it waited for two or three minutes until the 7.25 a.m. North Staffordshire train from Stafford to Manchester had passed on the down line at 8.54 a m., and had run to the down platform; but as soon as this train had stopped the cross-over road points were turned, and the disc-signal taken off for the empty Manchester, Sheffield, and Lincolnshire train to draw forward to the down platform behind the North Staffordshire train, so as to be in readiness to take its place at this platform, preparatory to leaving for Manchester at 9 a.m. The driver should, according to the usual practice, have been prepared to stop clear of the rear of the North Staffordshire train, but he states that when he tried to do so by the application of his vacuum-brake he found that it was not acting, and, when he had discovered that the reason for its not acting was that the release-valve flap was being kept open by his coat, it was too late for him to make use of this brake until just before he struck the other train. The driver states that he thought the North Staffordshire train had started, in which case he would not have had to stop until he had run 60 or 70 yards further along the platform, and also that, owing to the curve at the end of the loop, he could not have seen the brake-van at the rear of the North Staffordshire train until he had arrived at the south end of the platform; but I found upon trial that this latter part of his statement was quite incorrect, and I do not believe that he had the smallest intention of stopping, or that he took any steps to do so until he was close to the point of collision. It is no doubt quite possible that the release-valve may have been kept open in the manner described, for it is placed low down and just above the seat at the side of the foot-plate; but it is quite clear that the driver was not keeping a proper look-out, and that the collision was principally due to his carelessness. The fireman should not have been engaged in oiling the cylinders, and so away from his brake, when running up the platform behind another passenger train; and if he went to do this work without the knowledge of his driver, which, however, seems a little doubtful, he is much to blame. I do not think that, at a platform no longer than that at Macclesfield, a second train should be allowed to draw up to the platform until the preceding one has started. There is little, if any, time gained by it, for the second train must be stopped with only half its length against the platform, and be re-started when the platform is clear; and there is certainly some risk to the passengers in the train in front. The release-valve upon some engines fitted with the vacuum-brake is placed at the back of the fire-box and in front of the driver; and in this position it seems to me that it is much less liable to be opened accidentally than it is when placed as it was in this case.

NOTES.

Some Account of a Turret Clock.—We are informed that Messrs. Bailey Co., of the Albion Works, Salford, Manchester, are at present engaged in the manufacture of large turret clocks, which are being sent to various parts of the world. Two, we understand, are for the Jesuit Church, Spanish Town, Manilla, one of which indicates the time of day at nearly every chief city in the world, and the other will strike the hours and quarters on large bells. This firm has constructed and patented a clock arrangement quite different to that hitherto known as the modern turret clock. The improvements partly consist of a new arrangement of the various parts, whereby the frame carrying the several shafts is made much narrower. This result is obtained by fixing the drums upon which are wound the weight-ropes on the ends of the shaft, outside the framing, which it will be easy to understand allows of much greater range in the angle at which the ropes may be adjusted, as well as giving greater facility for inspection, also for winding purposes. It has also a novel feature in the flyer governing the striking mechanism. This is accomplished by means of brass rings surrounding the thin discs, the discs being attached at suitable points for adjustment. The clock strikes the hours, and will indicate the time on four 6 feet dials. The gravity escapement invented by Sir E. Beckett is here designed in a manner which permits the parts to be very substantial and easy of access for oiling, for adjustment, and for examination. The clock is on strong legs, and is entirely self-contained, the whole showing care in design.

London Chatham and Dover Railway.—The accounts of this railway for the past half-year have been submitted to and approved by the Board, and though subject to final audit, they show an available balance sufficient to pay a dividend of £2 per cent. on the Arbitration Preference Stock for the past half-year. This amount, added to the dividend of £2 5s. per cent. paid in respect of the half-year ending the 31st of December last, will make a dividend of £4 5s. for the year ending the 30th of June last, as against £3 17s. 6d. for the previous year.

The Phosphor-Bronze Company, Limited, have paid an interim dividend for the past six months at the rate of 10 per cent. per annum.

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LONG SPAN BRIDGES AND VIADUCTS, IN IRON, STONE, BRICK, AND TIMBER.

(*Continued from page* 203.)

CONSIDERING that in a continuous girder of two spans the maximum strain over the pier is expressed by $\frac{wl^2}{8d}$, there *may not* after all be any saving of practical value accruing from the adoption of this form of construction as compared with two discontinuous girders. We will now determine the theoretical saving, to which the practical saving will closely approximate in percentage of the quantities taken in each case.

Let there be a girder 200 feet in length loaded with 2 tons per lineal foot required, then make a comparison of the curves of strain for both forms of construction. First for two single spans.

At the centre of one span the ordinate will be $\frac{wl^2}{8d}$; let $d = \frac{l}{12}$. $l = 100$ feet, therefore

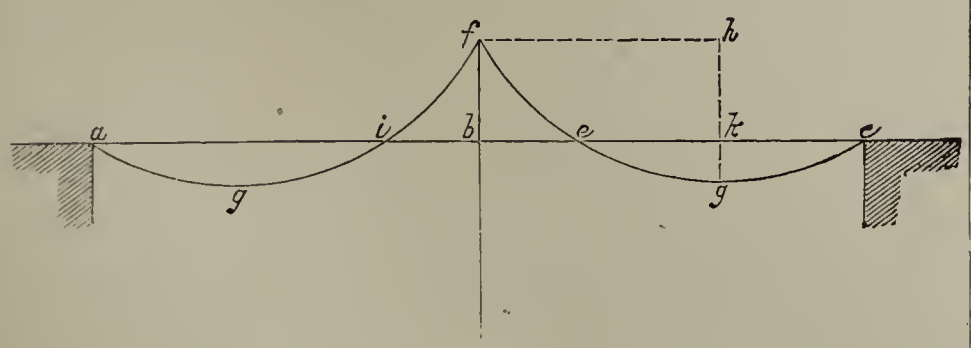
$$\frac{w.l^2}{8d} = \frac{w.l^2}{8 \times \frac{l}{12}} = \frac{3.w.l}{2} = \frac{3 \times 2 \times 100}{2} = 300 \text{ tons strain.}$$

For purposes of comparison, we may take the numerical value of the area of the curve of strain as the mean ordinate multiplied by the span, or chord, of that curve; the mean ordinate for the parabolic arc is $\frac{2}{3}$ of the maximum, as formed above, hence *for the two spans*, the total area will be:—

$$2 \times 300 \times \tfrac{2}{3} \times 100 = 40{,}000.$$

Next we will consider the continuous girder as loaded *uniformly* along *both* spans. In Fig. 8, let $a\ c$ be the line of

FIG. 8.



girder supported at the points a, b, and c, and let $agfgc$ represent the curve of strain. The areas agi, egc, ibf, and bfe must be ascertained and summed up for comparison with that found above. i and e are the points of contra-flexure, which in this case will be 25 feet from the point b, leaving $ai = ec = 75$ feet. The maximum strain on either of these lengths, assuming $d' = \frac{ai}{12}$ (as for calculation of strain on these parts $ai = l'$) will be

$$\frac{w.l'}{8d'} = \frac{3w.l'}{2} = \frac{3 \times 2 \times 75}{2} = 225 \text{ tons strain.}$$

And the area of the two curves agi and egc will be

$$2 \times 225 \times \tfrac{2}{3} \times 75 = 22{,}500.$$

The area $fbe = fbkh - fekh$; and $fekh = fegh - ekg$.

$$fb = hk = \frac{w.l^2}{8d'} \text{ (being the strain over the pier),}$$

$$\frac{w.l^2}{8d'} = \frac{2 \times \overline{100}^2}{8 \times \frac{75}{12}} = \frac{20{,}000}{50} = 400 \text{ tons strain.}$$

Again, $hg = hk + kg = 400 + 225 = 625$ tons, whence we find the area $fegh$ to be $= \frac{2}{3} \times 625 \times \{25 + 37{\cdot}5\} = 26041{\cdot}6$,—for $\{25 + 37{\cdot}5\}$ = semi-chord fh.

The area $egk = \frac{22{,}500}{4} = 5{,}625$, being one-fourth of the sum of the areas agi, egc.

Hence the area $fekh = 26{,}041{\cdot}6 - 5{,}625 = 20{,}416{\cdot}6$; and the areas ibf, $fbe = 2 \times \{62.5 \times 400 - 20{,}416.6\} = 9166{\cdot}6$

The total area of curves being,

$$= 22500 + 9166{\cdot}6 = 31{,}666{\cdot}6.$$

This, however, is not all; for, although in the case assumed we get the maximum strain over the pier, we do not get it on the parts ai and ec, but each part must be sufficiently strong for its own maximum strain, and this will occur here when only one span is fully loaded. We will assume half the load to be permanent and half live or occasional load.

The sum of the areas then for the dead load will be $\frac{31{,}666{\cdot}6}{2} = 15{,}833{\cdot}3$, and the other areas for live load will be those of curves corresponding to a load of one ton per foot on discontinuous girders, or for the two spans (for although they are not both taken as loaded together, they must each be strong enough to *take its turn* under maximum strain), and equal to 20,000 units.

Adding these numbers together we get 35,833·3, against 40,000 for separate girders, showing a saving of about 10 per cent. in this case, but this will vary with the ratio of dead to live load. Thus, if the former were one-fourth of the total load, we should obtain as the criterion number 7,916·6+30,000=37,916·6, showing about 5 per cent. saving.

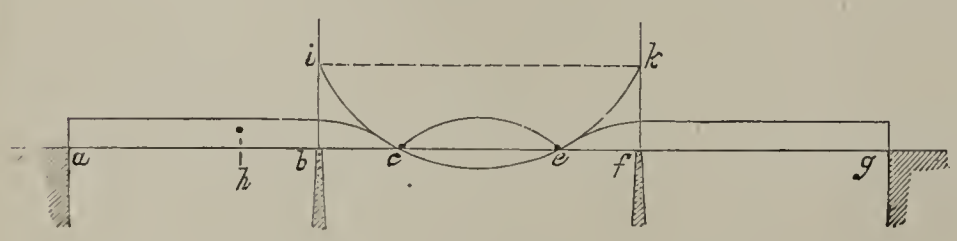
The conclusion arrived at is, that for carrying a permanent load, such as a wall or roof, where the load is always uniformly distributed over the whole length of the girder, it is always advisable to use the continuous girder; but when the load is of a mixed character, the ratio of permanent to occasional load must determine the most economical course to pursue.

The movement of the points of contra-flexure under variations of load has constantly exercised the minds of students interested in the question of continuous girders, and some perplexity has arisen in the matter, the difficulties surrounding practical experiment on this point being very great, and this has led to some rather curious suggestions.

As an instance, we will mention a proposal to make the points of contra-flexure practically stationary *by dividing the flanges* of the girders at such places as in the inner consciousness (we cannot say "judgment") of the designer might appear most suitable. The absurdity of such a course soon becomes obvious, for it is evident that the points of contrary flexure cannot thus be located permanently, and the result will appear in the production of abnormal strains in the webs, and in the impossibility of obtaining equilibrium of strains over the piers without disturbing the position of the line of vertical pressure on the bed plates; and, if a rocking plate be used, the line of pressure will not necessarily *be vertical* on the piers under some conditions of load, and then a lateral thrust will ensue tending to overturn the pier, and when the load is moving this thrust will act first on one and then on the other side of the pier, and thus tend to set it rocking, a state of things particularly to be avoided, as piers are designed usually to resist vertical stress only.

The mention of this brings us naturally to the question of *hinged* bridges carried by cantilevers, of which one form is shown at Fig. 9.

FIG. 9.



In this arrangement we find some of the economy of the continuous girder, and the methods of calculation are far simpler and more satisfactory. In the illustration the bridge is shown as consisting of three spans—*ab*, *bf*, and *fg*. *c* and *e* are the points at which the central part of the centre span is hinged to the cantilever ends *bc* and *fe* of the parts *ac* and *ge*. By thus forming the structure with hinges at *c* and *e*, instead of solid webs, we avoid the occurrence of abnormal strains on any part of the work, and these hinges can be so placed as to ensure stability in the side spans, corresponding as they do to invariable points of contraflexure. A limiting formula must be found for the length *bc*, which must not be increased far enough to endanger the stability of the ends of the side spans on their bearings at *a* and *g*. This, it will be seen, is a different case from the continuous girder, because of the fixity of the points *c* and *e*.

Of course there must be a margin of stability, but it need not be very great, as it is a question of stability purely, and we have means of ascertaining absolutely what the maximum disturbing force will be.

Let w = the dead load in tons per lineal foot, and w'' = the live load in the same terms; $l = ab = fg$; $l' = ce$; $u = bc = ef$.

Let the total moment of stability of *ab* on the land side be taken as ten per cent. more than the lifting moment acting on the farther side of the pier *b*.

This latter moment at its maximum will be that due to a full load on *bc* and *ce* and the minimum moment of stability will exist when *ab* is unloaded.

Taking the first, we find it to be

$$M=\frac{u}{2}\times u\{w+w'\}+u\times\frac{l}{2}\{w+w'\}=\{w+w\}\times\left\{\frac{u^2}{2}+\frac{ul'}{2}\right\}$$

The minimum moment of stability of the part *ab* will be

$$M'=\frac{l}{2}\times w\times l=\frac{wl^2}{2}.$$

Hence to give the margin proposed above the value of M' must not be less than 1·1 M.

We will now examine into the most economical proportioning of the superstructure, assuming for the occasion that the position of the piers will not materially affect *their* cost. Let $w+w'=1$.

In the first place, the positions of the points *c* and *e* are to determined. Let *bf* be the horizontal line of girder, draw *bi* and *fk* equal and at right angles to it, each representing the moment of strain over the pier. Let *icek* be the curve of moments of strain on the centre span and $l''=ik$. A minimum value must now be found for the area of the parts *ibc*, *kfe*, and *ce*. Proceeding as before we find the area for *ce*,

$$=\{l''-2u\}\times\tfrac{2}{3}\times\frac{\{l'-2u\}^2}{8}=\tfrac{1}{12}\{l''-2u\}^3,$$

the sum of the two remaining areas,

$$=l''\times\left\{\frac{l^2}{8}-\frac{\{l''-2u\}^2}{8}\right\}-\frac{l''^3}{12}+\frac{\{l''-2u\}^3}{12}.$$

The sum, therefore, of the three areas will be,

$$A=\tfrac{1}{6}\{l''-2u\}^3+\frac{l^2u-l''u^2}{2}-\frac{l''^3}{12}=\frac{l''^3-6l''u^2+18l''u^2-16u}{12}.$$

Differentiating we find,

$$\frac{d.A}{d.u}=\frac{-6.l''^2+36.l''u-48u^2}{12}=o, \text{ if a minimum occurs.}$$

$l''^2 - 6.l''u = -8u^2$. A quadratic equation thus solved.

$$l''^2 - 6.l''u + 9u^2 = 9u^2 - 8u^2 = u^2, \therefore l'' = 3u - u = 4u.$$

Hence $u = \frac{l''}{4} = \frac{l'}{2}$; and $A = \frac{1}{12}\left\{l''^3 - \frac{6l''^3}{4} + \frac{18l''^3}{16} - \frac{16l''^3}{64}\right\} = \frac{l'}{32}$.

The moment of strain over the pier will be,

$$= \{ w + w' \} \times \frac{l''}{4} \times \frac{l''}{4} + \{ w + w' \} \times \frac{l''}{4} \times \frac{l''}{8} = \frac{3.l''^2}{32}.$$

The point of contra-flexure in the part *ab*, under uniform load, may now be found, let x = its distance from *b*, the moment over the pier must be the same from whichever side it is calculated; hence,

$$\{ w + w' \} \times \frac{l}{2} \times x = \frac{lx}{2} = \frac{l''^2}{8}. \qquad (1)$$

The sum of the areas of the curves of moments of strain for the part *ab* will be

$$= \frac{\{ l - x \}}{12} + \frac{lx}{2} \times \frac{\{ l + x \}}{2} - \left\{\frac{\{ l - x \}^2}{8} + \frac{lx}{2}\right\} \times \tfrac{2}{3} \times \frac{\{ l + x \}}{2}$$

$$+ \frac{\{ l - x \}^3}{24} = \frac{l^3 - 2l^2x + lx^2 - x}{12}.$$

Differentiating we have,

$$\frac{d.A'}{dx} = \frac{-2l^2 + 8lx - 3x^2}{12} = 0, \text{ if a minimum occurs—}$$

$$l - 4lx = -\frac{3x^2}{2}; \; l^2 - 4lx + 4x^2 = 4x^2 - \frac{3x^2}{2} = 2.5x^2; \; l - 2x$$

$$= 1.58x; \; l = 3.58x \text{ or } x = \frac{l}{3.58}.$$

From equation (1) we have $\frac{lx}{2} = \frac{3.l''^2}{32}$.

Substituting x by its value we obtain—

$$\frac{l^2}{7.16} = \frac{3.l''^2}{32}; \; l^2 = .671.l''^2; \text{ and } l = .82.l''.$$

If, then, L = the total length of the three spans, the two side spans should each be $= \frac{82L}{264} = .31L$, and the centre span $.379L$.

Let the centre and side spans be respectively 100 feet and 82 feet, w = 1 ton and w'' = 2 tons, and let us see how the proportions come out for stability of the end parts. u will be = 25 feet, and l' = 50 feet.

$$M = \{ w + w' \} \times \left\{\frac{u^2}{2} + \frac{ul'}{2}\right\} \qquad \frac{625 + 1250}{2} = 2812.5 \text{ ft. tons.}$$

$$M' = \frac{w.l^2}{2} = \frac{1 \times 6724}{2} = 3362 \text{ ft. tons.}$$

So the moment of stability shows a margin of something over 19 per cent. over the maximum lifting moment, and the structure will be safe.

As in other cases, each part of the structure must be calculated for the maximum strain on that part.

The part, *ce* and also the parts *cb* and *cf*, will be fully strained when the centre span *bf* is loaded, the condition of load on the end spans making no difference, but the end span will be most strained when it is loaded, and the centre span empty; the moment of strain over the pier will then be $= \frac{3 \times w \times l''}{32}$ and the formula for determining the strain S on either flange of the side span at a point distant y from the pier *c*, *d* being equal to the depth will be,

$$S = \frac{\{ w + w' \}}{2.d} \times y^2 - \frac{\{ w + w' \}}{2.d} \times ly + \frac{3.w.l''^2}{32.d.l}.$$

The formula for a strain on the part *ce* will be the same as for an ordinary freely supported girder, and for the part *cb* or *ef* at a point distant y from the hinge becomes

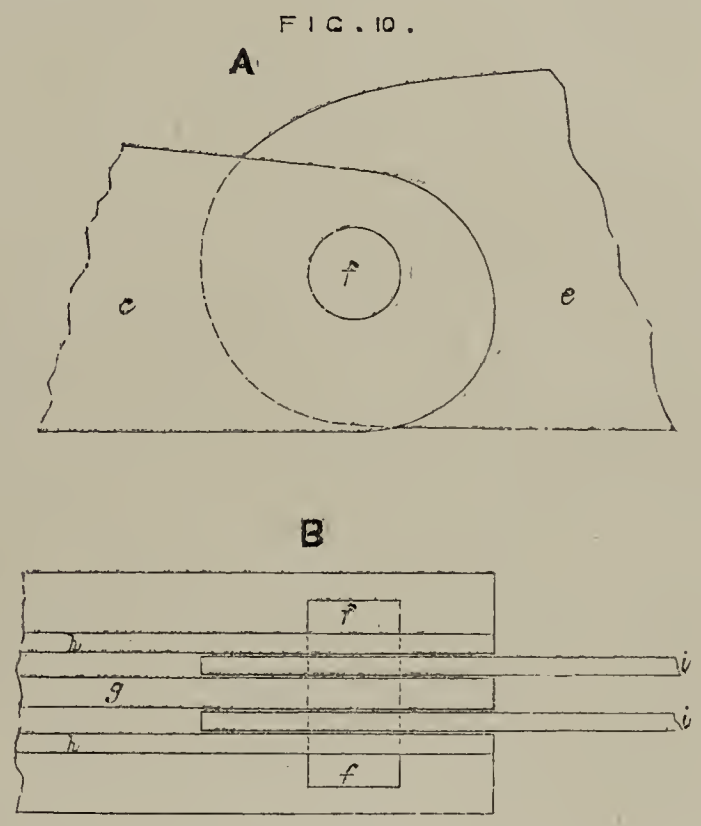
$$S = \frac{\{ w + w' \}.l'.y}{2.d} + \frac{\{ w + w' \}.y^2}{2.d} = \frac{w + w'}{2.d}\{ l'y + y^2 \}.$$

It may seem, considering that the side spans have not their maximum strains under the conditions assumed in determining their ratio to the centre span, that something might be gained by shortening them, but this would be regulated by the relation of dead to live load, and must therefore be worked out for each especial case, also keeping the stability question constantly in view.

Particular care must be taken in designing and manufacturing the hinges, the method to be followed in doing this we shall now describe:—

The pins forming the hinges must be calculated, both for shearing and for compression, a sufficient sectional area for the former, and bearing surface for the latter, being provided.

FIG. 10.



In Fig. 10 *A* is a side elevation and *B* a plan of one hinge. *C* is the end of the cantilever (*bc*, Fig. 9), and *e* one end of a main girder of the centre part (*ce*, Fig. 9), *f* is the hinge pin which passes through the plates *e*, shown at *ii* in plan, and through the plates *c*, shown at *h*, *g*, *h* in plan; these latter are strongly rivetted to the bottom flange of the cantilever. It will be seen that in the arrangement shown there are four shearing sections. The pin *f* must be accurately turned to fit the holes which must likewise be accurately bored through the plates *c* and *e* on both sides of the bridge, and in order to obtain true bearings the work should be done thus;—the plates *c* and *e* having been solidly rivetted on to the respective parts of the structure to

which they appertain, and the main girders connected together by their cross girders, the parts are to be placed in exact juxtaposition as they are intended to be when erected —the pin holes having previously been entered but left smaller than the finished diameter—and the alignment of the girders must be very carefully adjusted—a boring bar sufficiently long to take both sides of the bridge is to be passed through the pinholes and steadied on each side of each set of hinge plates by suitable poppet heads, to obviate chatter of the tool, the pin holes are then to be carefully bored out to the finished size at the same time, thus the axial truth of the pins on both sides of the bridge will be ensured and all subsequent wrenching and jarring avoided.

On each pin there will be one quarter of the total load on the central part of the centre span, that is, the strain on each pin is,

$$S = \tfrac{1}{4}.\{w + w'\}.l'.$$

For example, let the centre part referred to be 120 feet span and made to carry a double line of railway, having two outside main girders and cross girders carrying the floor, The dead load may be taken as 2·25 tons per lineal foot, and the maximum live load as 2·9 tons per lineal foot; this will give for the load upon one pin—$S = \frac{1}{4}\{w + w'\}l' = \frac{1}{4}.\{2{\cdot}25 + 2{\cdot}9\} \times 120 = 154{\cdot}5$ tons, no inconsiderable load to trust on one pin. Taking 5 tons per sectional square inch as safe shearing strain, the area required will be $\frac{154{\cdot}5}{5 \times 4} = 7{\cdot}725$ square inches in each shearing section; this corresponds to to a diameter of 3·14 inches, and corresponding to this must be a sufficient bearing to resist the compression and distribute properly the shearing strain as otherwise the plates if too thin will cut into the pin by the compression of the metal, and it may be thus *sheared in detail*. The bearing on the pin is equal to its diameter multiplied by the thickness of plate resting upon it, the total area required for each hinge, allowing 5 tons per square inch as working load in compression, will be $7{\cdot}725 \times 4 = 30{\cdot}9$ square inches. For convenience make the pin 7 inches in diameter, then there will be required in the plates *i i* a total thickness

of $\frac{30{\cdot}9}{7} = 4{\cdot}41$ inches, or $2\frac{1}{4}$ inches say for each plate *i*; similarly the plate *g* must be $2\frac{1}{4}$ inches thick, and the plates *h* $1\frac{1}{8}$ inch each; this is working to the nearest $\frac{1}{8}$ of an inch above that required by calculation. The plates should be planed so that they may be brought close enough together to prevent transverse bending stress from coming upon the pins, and they should be thoroughly greased in order to prevent the hinges from rusting up.

The width of plate beyond the pin holes must also be determined. This is not a detail for theorising much upon, but practice indicates that on that side of the pin which would burst out through weakness, the width of margin should be $1\frac{1}{2}$ diameter of the pin, hence there should be $10\frac{1}{2}$ inches below the pin in the plates *c*, and $10\frac{1}{2}$ inches above it in plates *e*; the pin may be secured in position longitudinally by cotters driven through the ends of it outside the hinge plates. We now pass from these general considerations and comparisons and proceed to the actual designing and construction of long span iron bridges, the flooring being that part which first claims our attention to its details.

Floors may be divided into two principal classes—those covered with iron plates, and those covered with timber, the former require no horizontal bracing, as the plates form the best bracing that can be obtained, which, together with their durability, accounts for their almost universal adoption in England, though in countries where timber is plentiful and skilled labour for erection scarce, this material is found more convenient, but in foreign and colonial work of all descriptions there are contingencies liable to arise which materially influence the character of our designs.

It is a certain fact that railway bridges are always made a great deal stronger than is necessary (of course, we assume the designer to be a competent engineer, and one who will not commit palpable blunders or omit to allow for wind pressure, &c.), being calculated for a train of engines and tenders, which probably will never fill them after the first testing, at least, on English railways, and it will most frequently be found that even with this excessive load the strains will not come up to those allowed by the Board of Trade—that is, 5 tons per sectional square inch.

In the first instance, we will take as an example a single line of railway running between two main girders, the clear width between which must be 15 feet.

If the cross-girders be spaced close together—as, for example, 4 feet from centre to centre—distributing girders must be introduced longitudinally to distribute the concentrated loads over these cross-girders, otherwise we may find only the alternate girders acting at a time, as would be the case with a wheel-base of eight feet; on the other hand, if the cross-girders are spaced wider apart, to suit such base, then rail-bearers must be put between them under the rails. Let us ascertain which in the present case will be the more economical. Although the cross girders are to some degree strengthened by their being firmly rivetted to the main girders, yet it will not do, as we cannot ascertain the amount of strength so added to regard them but as girders freely supported at both ends. Let the bridge be 150 feet span, the cross-girders be placed 4 feet apart centre to centre, with a distributing girder passing down the centre. The flooring, including cross and distributing girders, floor-plates, 6-in. ballast, and permanent way, may be assumed as weighing altogether 100 lbs. per superficial foot, the live load being one pair of locomotive driving-wheels 16 tons, of which there will be 8 tons at 5 feet distance from each end of the girder. Let the cross-girders have an *effective* depth of 15 inches.

It will be observed that the maximum load will be upon two cross-girders having between them, for the time being, an idle girder, except for the intervention of the central distributing girder.

Let W = the portion of the 16 tons load taken by the distributing girder to the idle girder and applied at its centre, then the maximum strain on this girder will be $\frac{W.l}{4.d}$ where l = span and d = depth of cross girder; then if W' equal the total live load left to be carried by the loaded girder, the maximum strain on that will be $\frac{W'}{2d} \times 5$. Now as all the girders pass under indentical conditions as the load rolls on they must all be of the same section, hence the distributing girder must be arranged to give the same maximum strain on both the girders under consideration, wherefore

$$\frac{W.l}{4.d} = \frac{W.' \times 5}{2d} \therefore W.l = 10W'; \quad W \times 15 = 10W'; \quad W = \tfrac{2}{3}W'$$

hence the total live load being 16 tons, $W = 6{\cdot}4$ tons, and $W' = 9.6$ tons, and the maximum strain on any girder will therefore be

$$\frac{W' \times 5}{2 \times d} = \frac{9\,6 \times 5}{2 \times 1{\cdot}25} = 19{\cdot}2 \text{ tons.}$$

This, at 5 tons per sectional square inch, requires in each flange an area of 3·84 square inches, to which must be added the area required to carry the dead load, which load is, 100 lbs. × 4 feet × 15 feet = 6000 lbs. = 2·68 tons, the strain due to this uniformly distributed load is

$$\frac{2{\cdot}68 \times 15}{8 \times 1{\cdot}25} = 3{\cdot}975 \text{ tons; requiring } \frac{3\,975}{5} = .79 \text{ sq. in.}$$

making a total of 3·84 × ·79 = 4·63 sq. in. in each flange.

For the top flange two angle-irons 3 in. × 3 in. × $\frac{3}{8}$ in. thick will be the nearest we can get; and for the bottom, allowing for rivet-holes, two angle-irons $3\frac{3}{4}$ in. × 3 in. × $\frac{3}{8}$ in. thick. The *effective* depth between the centres of gravity of the flanges being 15 inches (1·25 ft.), the total depth of web will be $16\frac{3}{4}$ in., and this web must be $\frac{1}{4}$ inch thick, thus giving for the total sectional area of the cross-girder 13·75 sq. in. = 137.5 lbs. per yard. The girders being taken as 2 ft. 6 in. wide, the total length of cross-girder from web to web of main girder will be 17 ft. 6 in. The weight for the running section will be 802 lbs. There will also be six tee iron stiffeners 16 inches long, 6 in. × 3 in. × $\frac{1}{2}$ in. thick on the web, which, at 15 lbs. per foot, will weigh 120 lbs., and six packings behind the tee-irons, 6 in. × 10 in. × $\frac{1}{2}$ in. = 50 lbs.; in end brackets to connect the cross-girder to the web of the main girder, four angle-irons, 3 in. × 3 in. × $\frac{1}{2}$ in., 16 in. long, = 53 lbs., and packings for them, four 10 in. × 3 in. × $\frac{1}{2}$ in., say 17 lbs., making in all, with 5 per cent. allowance for rivets, a weight of 1,094 lbs. per cross-girder. In 150 feet span there will be 37 cross-girders, making a total weight for cross-girders of 18·07 tons. To this we must add the weight of the distributing girder to get the entire weight of the framework of the flooring. Eight feet of the distributing girder comprised between any two cross-girders will, in its turn, be acting to carry at its centre the load 6.4 tons, as ascertained above. Let the distributing girder be 8 inches deep, then at 5 tons working strain per sectional square inch the area required will be, the load being at the centre,

$$\frac{6{\cdot}4 \times 8}{4 \times {\cdot}66 \times 5} = 3{\cdot}84 \text{ sq. in.}$$

The angle-irons will therefore, be the same size as those used for the cross-girder, and the web will be 8 in. × $\frac{1}{4}$ in. Then, allowing 10 per cent. for rivets and joint-plates, the weight of the distributing girder for the whole length of the bridge will be 2·84 tons, which, added to the weight of the cross-girders, makes 20 91 tons.

We will now see how the weight will come out for girders 8 feet apart, centre to centre, with rail-bearers between.

Working upon the same data as above, the dead load on the rail bearers will be 83 lbs. per superficial foot (the weight of cross-girders being deducted from the 100 lbs. previously taken). The total dead load then on each bearer will be 83 × 8 × 5 = 3,320 lbs. = 1·48 tons, the bearers being 5 feet apart and 8 feet long. Let them be 9 in. deep. The maximum live load will be 8 tons (one driving wheel) in the centre of the rail-bearer. Hence, at 5 tons per square inch the flange area required will be

$$\frac{1{\cdot}48 \times 8}{8 \times {\cdot}75 \times 5} + \frac{8 \times 8}{4 \times {\cdot}75 \times 5} = 4{\cdot}65 \text{ sq. in,}$$

The top angle-iron must therefore be $3\frac{1}{2}$ in. × 3 × $\frac{3}{8}$ in; those in the bottom flange (rivets being considered) must be $3\frac{1}{2}$ in. × $3\frac{1}{2}$ in. × $\frac{3}{8}$ in.; the web will be 11 in. deep (for an effective depth of 9 in.), and $\frac{1}{4}$ in. thick; hence the weight per foot will be, including rivets, 45 lbs. There will be two rows of bearers running the whole length of the bridge; therefore their weight will be 300 ft. × 45 lbs., = 13,500 lbs., = 6·03 tons; the dead on one cross girder will be 15 × 8 × 100 lbs. = 12,000 = 5·35 tons. The live load 8 tons at 5 feet from the bearing points on each end of the cross-girder. The flange area required will therefore be, at 5 tons strain per square inch,

$$\frac{5{\cdot}35 \times 1{\cdot}5}{8 \times 1{\cdot}25 \times 5} + \frac{8 \times 5}{1{\cdot}25 \times 5} = 8 \text{ square inches,}$$

the cross-girders being kept the same depth as before. The top flange may be made of two angle-irons 5 in. × 3 in. × $\frac{1}{2}$ in. and the bottom one 6 in. × 3 in. × $\frac{1}{2}$ in., the web being $16\frac{3}{4}$ in. × $\frac{1}{4}$ in. The weight, therefore, of each cross-girder will be, including rivets, 1,548 lbs. There will be 18 of these cross-girders, making the weight in all 1,548 × 18 = 27,864 lbs. = 12.44 tons. Adding to this the weight of the rail-bearers, the total is 18.47 tons, to compare with 20.91 tons for floor-girders in the mode of construction previously considered. This shows a saving of upwards of 12 per cent. by adopting the girders placed 8 feet apart; and although at first sight this may appear somewhat anomalous, yet a little careful reasoning on the matter will elucidate the cause, and although by some the fact alone of the weights standing as

they do may be considered sufficient, yet by showing the *rationale* of the results the mind is trained to a system of correct premising on any analogous cases that may arise.

At the first glance it might, and to the inexperienced does, appear that by widely spacing the cross-girders they have to carry the rail-bearers in addition to the other load, which in both cases comes ultimately upon them. On the other hand, however, there are some practical and some theoretical points to be taken into account which exercise influences materially changing the aspect of affairs.

We cannot put in a less web than one ¼in. thick practically, and this is sufficiently strong for girders eight feet apart, hence by using the latter we save directly nineteen webs' together with their stiffeners, packing, &c.

Again, if we have the rail bearers in the second case, there was in the first the distributing girder weighing 2·84 tons as against 6·03 tons for rail bearers. The theoretical point rests upon the application of the load taken up by the distributing girder, here we found that the loaded cross girder had its live load reduced from 16 tons to 9·6 tons, so that although the loaded girders correspond in number to the unloaded, yet the loads are not halved, although all the girders are equally strained, the reason being that the intermediate cross girders receive their share of the load entirely in the centre, hence have a larger proportional maximum strain than the directly loaded girders.

There is no doubt that a buckled plate flooring does to a very great extent distribute the load along the cross-girders, and if the sleepers are not put directly over the cross-girders it will be so much the better, as then the load must be more distributed ; but unfortunately we cannot in practice avail ourselves of such advantages, for even if we use the greatest care in originally laying down the permanent way, we can never be sure what will be done when the rails are renewed and the way relaid, and we may be tolerably sure that the permanent way men will not trouble about the bridges, so we are compelled to go on wasting materials and money to provide for contingencies that ought never to arise.

Next let us take a bridge carrying two lines of railway, by means of three main girders allowing 15 ft. clear for each track, and ascertain what can be saved in the cross-girders by making them continuous throughout the bridge.

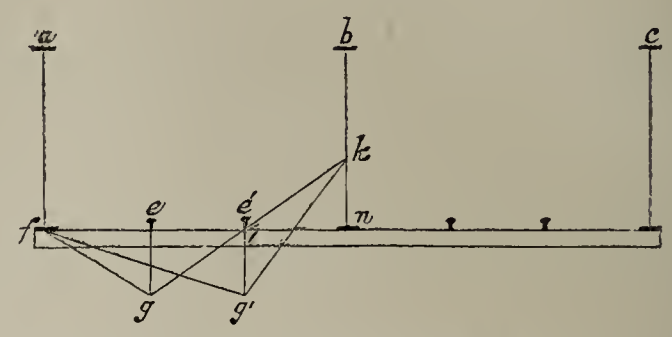
If taking them as 8 ft. apart they were made discontinuous, their total weight would be, with rail bearers, 2 × 12·44 tons = 24·88 tons.

A particular case presents itself if the girders are continuous across the bridge, and it is one that requires consideration, both in respect to the cross girders, and also to the central main girder.

The main girders, in respect to live load must evidently be designed, the centre one capable of carrying one line of railway, and the side girders each to carry half a line of railway. Supposing one track to be loaded with a train of engines and tenders weighing 1·45 tons per foot then there will be a sort of balancing between this train on one side of the centre girder and the far side girder on the other.

Regarding the cross girder as merely *supported* on the side girder nearest to the train, it is evident that the train can produce on the cross girder at its point of attachment to the centre girder, a moment which is ascertained as follows :—

FIG. 11.



Let *a*, *b*, *c*, Fig. 11, be the three girders 2 ft. 6 in. wide each, then if they are equally loaded on both tracks the maximum moment below *b* would occur. From the centre of *a* to the centre of *b* is 17·5 ft. *e*, *e'*, are the points of application of the load, which for our present purpose, the determination of its effect on main girders, is to be taken as uniformly distributed, so that along the line *e* or *e'*, there will be a load of $\frac{1·45}{2} = 0·725$ ton per lineal foot. We will deal with these loads separately, and sum the results subsequently.

Let *fgk* be the line of moments for the load at *e*, and let it intersect the horizontal line at *i*. Then *eg* will be the moment of strain at *e* and *kn* that at *n*, the centre line of the centre girder.

Now, if the girder were free at both ends the shortening of the top flange from *e* to *n* would be one-half of that due to the moment at *e*, hence if it be fixed at *n* the moment there will be one half the moment at *e*.

Calculated for free ends, this moment will therefore be for one foot in length of bridge $\frac{·725 \times 11·25}{17·5 \times 2} \times 6·25 = 1·45$ ft. tons

Here .725 tons is the load per lineal foot on rail *e*, 11·25 ft. = distance *en* 6·25 ft. = *fe* and 17·5 ft. = *fn*. In like manner and similar moment will accrue from the load on *e'*, making together a moment = 2·9 tons for one lineal foot of girder.

Upon the data previously used the weight of one outside girder and its attachments may be taken at 7½ cwt. per lineal foot, or 0·375 tons, multiplying this by the distance from *c* to *b*, centres we find that to *lift* the outside girder from its bearings would require for each lineal foot a moment of 0.375 × 17·5 = 6·56 tons hence there will be ample stability.

The point *n*, however, of the cross girder will not be held with the same rigidity, as if the part between *b* and *c* were also fully loaded, for that part will itself yield, and we shall be brought practically to a case of a continuous girder of two spans, in which the live load for one cross girder is 8 tons on each rail and the dead load 100lbs. × 8 ft. × 17·5 ft. = 14,000lbs. = 6·25 tons per span, a ratio which will give very little advantage, and we might say practically none as the section of cross-girder being probably carried through un-

altered, the weight would remain the same, and even if it were varied, with these ratios hardly 5 per cent. could be saved on the cross girders amounting only to about 1¼ tons, while the centre girder would have to be strengthened for the full additional load due to such construction, while at the same time the side girders cannot be correspondingly reduced, their maximum strain being when only one track is loaded.

From this it appears that the best course is to make the cross girders discontinuous, running only from main girder to main girder so avoiding the introduction of unnecessary disturbing agencies on such main girders.

It is highly necessary to consider all these various matters connected with different modes of construction, and indeed the *earnest* student will appreciate the desirability of, in the first instance, *thoroughly considering* all the bearings of the various general cases, and so settling once for all in his own mind the proper course to be pursued, and this will probably save much time in subsequent practice, for as different structures are called for, and especially, when economy is a prominent feature in the instructions, such details will suggest themselves for examination, and then their investigation will lead to unreasonable delay, or they will be dealt with in such haste, and so at hap-hazard, half calculation and half guess, as in the end to leave no really settled conclusion on the mind of the examiner, and this gradually leads to a want of self-confidence in the designer, and it is very certain that if a man has not confidence in himself no one else can be expected to have confidence in him.

(*To be continued.*)

RAILWAY SIGNALLING.

INTERLOCKING POINTS AND SIGNALS.

(*Continued from page* 213.)

THE signalling arrangements and appliances of the Waterloo terminus of the London and South Western Railway Company afford another good example of efficient means of traffic management in this country. The greater portion of the mechanical appliances on this line are by Messrs. Stevens & Sons, and are of the usual simplicity and excellence well known to many of our readers. And when we bear in mind that over 600 trains are daily conducted in and out of this terminus with safety, rapidity and punctuality, we may readily infer that the arrangements of traffic are fairly up to the standard. Of course, all the arrangements at this station are not so modern, uniform and simple (as a combined system) as the example given in our last number. For although the apparent complex nature of the London and Brighton Terminus has been said by some railway authorities to be a great tax to other Companies' drivers running over these roads, still the whole system is incontestably most uniform, and merely a repetition or combination of the same standard elements. Whereas the Grand Junction, or A box at Waterloo, is provided with fifty-five point and signal levers, on Stevens & Sons' principle, and 104 on Saxby & Farmer's system, and a considerable amount of electrical inter-communication is adopted of more complex character than in the former example. The A box, which mainly controls the traffic of the terminus, is built on girders arranged transversed or across the roads, and Messrs. Stevens' and Saxby's frames provided therein are placed and worked back to back, being suitably interlocked by tappet rods extending under the flooring, so as to prevent any conflicting operation of the otherwise two distinct frames.

There are four principal roads west of the A box, leading to and from the station, alphabetically designated *a*, *b*, *c*, and *d*, counting from the main line or south side, towards the Windsor roads on the north.

These four roads are in connection with twelve station roads, numbered respectively from one to twelve, having corresponding arrival and departure signals mounted above the A box.

About 300 yards from the last mentioned box is the B cabin, opposite to which are situated the stop signals for the *Up* and *Down* Windsor lines; while at the station end of Westminster Bridge Road there are four stop signals which control the whole of the traffic over the four lines above mentioned, two relating to the *Up* and *Down Main* line, and two to the *Up* and *Down* Windsor roads respectively. Thus, for example, all trains approaching the terminus, must first obtain permission to proceed from the two up stop signals last referred to, when subsequently the drivers learn from certain of the twelve signals over the A box, the bay or platform into which they are to travel. As all terminal roads are used alike for in and out traffic, there are twenty-four signals (in two sets of twelves) carried by two posts on the top of the A box—six up and six down signals on each post. On approaching Waterloo Station, the signals on the post to the left hand side relate to Windsor traffic—the six on the left of this post being for the up or arrival trains, while the exactly similar signals carried on the right of the post, refer to down or departure traffic. The post to the right hand of the box is provided with twelve exactly similar signals for controlling the up and down main line trains. All these

twenty-four signals work in concert, and control by starting gear, the four *Up* and *Down* stop signals governing the four roads *a*, *b*, *c*, *d*, so that when any one of these is pulled "off," a signal for a station road is simultaneously operated or given. Platform signals are also provided for indicating to drivers of arriving trains, the condition of the bays signalled for their reception, similar to the arrangements already described with reference to the London Terminus of the Brighton Railway, with the exception that one semaphore (capable of occupying three positions) is employed in lieu of a separate auxiliary signal. Thus as a driver passes under the A box, and at the same time receiving definite intelligence as to the road he is going to occupy in the station, subsequently learns by the position of the arm or light of his platform arrival signal, whether the bay be absolutely clear up to the buffer stops, or whether partially occupied by standing vehicles, &c. For this purpose the raised attitudes of the arms are considered as "stops," the half or angular positions "caution," or "draw in slowly—some partial obstruction on the road," while the arms quite down indicate "lines quite clear."

For increasing the safety of their operations in the night or in foggy weather, electrical repeaters are arranged within the boxes, so as to clearly indicate to the signalman the exact positions of these signals. Platform starting signals with auxiliary discs are also provided for despatching down trains, the semaphores giving the permission to proceed, and the discs the roads the trains will traverse on their way to the four principal roads before alluded to, and in an exactly similar manner to that described with regard to the Brighton Railway.

The platform arrival and departure signals are operated by separate station boxes, but receive all their instructions and permissions from the A box.

The shunting operations of the stations are conducted by special signals provided for such purpose.

The block signalling and other electrical instruments used on this Company's line are almost exclusively by Mr. Preece.

CONTROLLING AND LOCKING LEVEL CROSSING GATES.

We will now proceed to briefly consider the extension of the interlocking system to controlling the operation of level crossing gates, so as to ensure all signals being placed and locked in their "danger attitudes" when the gates are shut across the railway, and opened to ordinary public road traffic, and *vice versa*, which is obviously a most valuable precaution for the safety of the public.

As early as 1853, we learn of a Mr. G. Richardson inventing means for reducing the liabilities of accidents at level crossing gates, by connecting the gates on either side of the line in order to simultaneously open or close them, so as to form alternately barriers across the public road and the railway, "danger and all-right signals" being likewise worked in concert by such operations. Ten years later, *i.e.*, 1863, a Mr. Charles Henry Lea, of Staffordshire, procured Letters Patent for "improved apparatus for opening and closing the gates of railway crossings, which apparatus also acted simultaneously upon the signals." This was probably the real origination of the present systems of safety adopted at level crossing gates. By this invention, one operator was enabled by a movement of a single lever to open or close both gates, and at the same time set the up or down signals in the required positions of danger or safety. For this purpose the gates were mounted on footstep bearngs and connected by links to levers capable of vibrating about fixed fulcra. Some ends of these levers were suitably connected together by rods running along the "six-footway," so as to simultaneously receive and impart similar motion, while the outer end of one of these levers was extended and connected by chains to two levers, the movement of one serving to open the gates and the other to similarly close it. The usual semaphore signals of the up and down lines were then connected to these two gate-levers by means of chains or wires passing round pullies, so that by opening the gates for the public road the signals were all put to danger, and conversely when closed were released by the action of counterweights or their equivalents.

Mr. Lea made several improvements upon his original invention, keeping pace with new competitors in the field, and later on we shall have occasion to fully explain some recent apparatus of this gentleman's designing.

At places where a railway crosses a public road at or about right angles, it is usual to employ two gates only, of the same breadth as the span of the line, so that by turning them upon pivots in arcs of about 90 degrees, they alternately serve as barriers against the road or line. In cases, however, where a railway intersects a road at a more or less acute angle, it is usual to employ four gates, a pair on either side.

In the former case, the angular distances to be travelled by the two gates are equal, and therefore the gearing for operating the same is very simple; but it will be readily seen that in the latter example, the two gates situated at the obtuse angles of the crossing have to be actuated with a greater angular velocity than those at the acute angles of the same, in order that the two different arcs of motion may be effected in the same time, and thus the gates simultaneously, opened or closed.

The early simultaneous operation of level crossing gates and signals has now been sufficiently noticed, and we will therefore pass on to briefly examine the general principle of the interlocking system, as at present extended to the control of such gates and signals.

The gates are usually operated by levers placed in boxes or cabins situated at a convenient distance, similarly to point and signal levers, the requisite motion being imparted to them through the intervention of racks and pinions, or chains and pullies, &c., so as to open or close the gates simultaneously; and the operating levers are interlocked with the signal levers in any convenient manner as described in our

previous numbers. In order to prevent the gates being moved out of their proper or set position by others than the signalman in charge, "stops" are provided to hold them in position until safe to be released. The release of the gates by the withdrawal of the "stops" being effected by another lever interlocked with the signals and the lever for moving the gates; so that the latter lever cannot be moved until the former has been moved to withdraw the stops, in a somewhat similar manner to the functions of the locking and operating levers of facing points.

The stops are formed with bevelled or inclined faces on one side, so that the gates may pass over them in the one direction by slightly depressing them, but cannot be returned against their opposite or perpendicular faces, unless they be depressed by the operating lever in the box. These stops or pieces which govern the movements of the gates are usually connected by suitable intermediate gearing with the lever, so that when the stops to the ordinary road are depressed, those in the six-foot way are raised, and *vice versâ*. It will therefore be now understood that the first operation in working crossing gates, is to withdraw the stop bolts or equivalents holding the gates in either position, which can only be effected when the signals are set in accordance.

Assume a set of gates to be open for a railway, and therefore closed against the public road,—to reverse the circumstances, the operator in charge of the levers would first have to withdraw the stops or bolts holding the gates in the aforesaid position, and this could only be achieved when he has placed all his up and down signals at danger, through the different operating levers being suitably interlocked. This having been effected the gate stop or locking lever is liberated and free to be moved, which being done (so as to depress or withdraw the stops or bolts holding the gates) immediately locks all the signals in their danger altitudes. Then by means of another lever before mentioned, the gates are moved into their opposite position, or open to the public thoroughfare, thereby passing over the inclined faces of the other stops or bolts, and becoming secured against return as before described. The lever which locks the gates is also interlocked with the signals, so that simply removing the stop or bolts does not release the signals.

It will be obvious to our readers that all crossing gates must necessarily be within easy view of the operator (wherever he be stationed), so as to prevent any liability of his moving the gates while persons or vehicles are in the way.

We will now pass on to consider Mr. C. H. Lea's improvements upon his original invention of 1863, which were patented six years subsequently, viz., in 1869, and rela ed to certain simplifications and modified arrangements and developments of apparatus for opening, closing, and locking Railway Level Crossing and other gates, and also simultaneously acting on "near or distant signals." His improvements of this date were further extended to the independent actuation of semaphore and other signals placed at such crossings, for the purpose of affording additional security or guidance for the operation of the opening and closing apparatus, and likewise to appliances used in connection with the above, for locking the gates when closed, and for raising or lowering such gates when necessary.

Fig. 258, Plate CLXV, represents a part sectional plan of the above-mentioned improved apparatus for opening and closing level crossing gates, and Fig. 259 is a side elevation of one pair of such gates, illustrating the connections of such apparatus at their heels.

Fig. 260 shews a plan of the apparatus for connecting the distant or other signals, with working gear of the gates, operated by a hand lever; while Fig. 261 is a part side elevation of the apparatus, showing the hand lever and gear used in connection with the locking apparatus of the gates.

Fig. 262 is a part sectional plan of the gate-locking apparatus arranged beneath the ground, and Fig. 263 a sectional detail view of the stop-box with the necessary mechanism for holding the gates in the required positions in relation to the railway or public road.

The apparatus for actuating the gates consists of two levers *A* and *B*, Fig. 258, mounted on fulcra within a suitable enclosure *C*, and placed in connection with a hand lever in any convenient manner, as shewn by rod *D*. These two levers are connected together at their inner ends by slotted pin joints *a*, while their outer extremities are attached to the rods *E*, connected with the heels of the gates at *F*. For purposes of convenience, only one gate connection is shewn. But it will be readily understood that in practice, the parts are similarly multiplied by duplicate gear attached to the heels of all four gates, so that by the operation of one hand lever placed in connection therewith, all four gates are caused to open or close simultaneously.

The gates are mounted on footstep bearings *G*, Fig. 259, provided with a set of ajusting screws *g*, for maintaining the necessary clearance of the gates, so as to avoid any possibility of jambing.

H are adjusting screws and plates for raising and lowering the gates, and *I* are guards for keeping the heels from becoming fouled or choked with dirt or other obstructions. The operating hand lever before referred to (marked *X* in Fig. 260), in connection with the apparatus above described through the intervention of the rod *D*, is also placed in connection with the distant signals by means of the rod *L*, working a counterweighted lever *M* actuating such signals. A chain or wire is connected with the weighted lever and passes over the pulley *n* to the signal gear.

The signal hand lever *O* is in connection with the rod *P*, communicating with the bent lever *q*, to which is attached a bolt *R*, also controlling a similar lever *S*, working the signals through the rod *T* and lever *U*.

By moving the lever *O*, the bolt *R* is caused to pass through a box *V*, so as to obstruct a passage formed in it, thus preventing any movement of the rod or bar *W* working in concert with the hand lever *X*, so that the gates cannot be moved until the bolt is withdrawn by the return of the lever *O*. The act of withdrawing the bolt from the box *V*, works a danger signal at the crossing, and at the same time leaves the hand lever *X* free to work the gates.

To the hand lever *Z* is attached a rod *Y* (*see* Figs. 261, 262) for actuating the stops mechanism *b* through the rod b^1, and cranked lever *z*,—this lever being also in connection with the counterweighted lever c^1 (Figs. 260-1), to one end of which a notched lever or bar *e* is fixed. Beneath the framing of the apparatus (Fig. 261) is mounted a sliding bar or spindle *f*, connected by the wire f^1 to the bell crank lever g^1, attached to a foot treadle at h^1. By depressing this treadle the end of the bar *f* is moved out of the notches on the lever *e*, so as to release the lever *Z*, which at once falls over to its forward position by virtue of the counterweight connected therewith, thereby raising the gate stops on the public road and depressing those on the railway. The sliding bar *f* is normally held engaged with the notches formed on the lever *e*, by a weighted chain *j i* connected thereto, in which position the stops on the public road are held down and those on the railway raised.

At Fig. 262 is shewn the arrangement of mechanism for locking or securing the crossing gates, when moved into the required position.

It consists of four stop boxes *b*, two only of which are here shewn, connected by rods *k* to a centre cross lever *l*, fitted with adjusting mechanism to regulate the stops. Two of these boxes are placed on the railroad and two on the public road; when the hand lever *Z* is moved to its forward position, the stops are raised on the public road and depressed on the railway, thereby allowing the gates to be moved by the apparatus in connection with the lever *X*. The rod b^1 is connected to a bent lever *m* (Fig. 263) working inside each box on a shaft *n* running through the box. This bent lever is connected to the back stop *o* by a pin *p* fixed to it, and working in a slot formed in the bent lever; the other end of the bent lever is connected to the rod *k* which passes out of the stop box and is connected to the centre cross lever *l* (Fig. 262). The catch stop *q* is fixed to a lever *r* which works on a shaft S, also running through the box *b*, and is attached by a rod *t* to the bent lever *m*, which has fixed to it a piece *u* with a hole in it for the rod to work in. When the hand lever *Z* is moved to its forward position, the catch stop *q* (which is balanced by a weight *v*) allows the gates to pass over it. As soon as the gates are closed the weight brings it back to its proper position, thus locking the gates, and rendering the mechanism self-acting.

These improved appliances in connection with the operation and control of level crossing gates, are extensively used by the North-Eastern and other leading railway companies of this country.

Another good example of apparatus for controlling the operation of railway crossing gates, will be found in Mr. P. Black's Invention of 1877—of the firm of Messrs. Saxby & Farmer.

According to this invention, each gate or pair of gates is provided with a bolting apparatus, one part of which on the gate, or on one of them, is connected by suitable rods and levers to a lever interlocked with those used for working the points and signals, and another part of which on the post or other gate operates as a bolt, which can be moved by an attendant at the gate or gates. When such attendant closes the gate (thereby leaving the line of railway free) he shoots the bolt so as to secure the gate in that position, and by doing so he removes an obstruction to the movement of the other portion of the bolting apparatus, so that the signalman is enabled to move the lever connected to that portion. The signalman, by moving the said lever, effects two objects, namely, the one in locking the bolt at the gate so that it cannot be withdrawn, and the other in unlocking such of the point or signal levers as may be safely worked while the gate remains bolted.

When it is safe and necessary to open the gate, the signalman first moves such of the point and signal levers as it may be necessary to move for the purpose of closing the line to traffic, and he thereby unlocks the lever communicating with the bolting apparatus on the gate. He moves that lever, thereby releasing the gate bolt, which the attendant at the gate can then withdraw, but this withdrawal of the bolt automatically places the obstruction above mentioned, which prevents the lever from being again moved until the gate is again bolted, and this lever being interlocked with the point and signal levers the signalman is thus prevented from moving them so as to give passage for a train until the line is cleared by the closing and bolting of the gate.

Figs. 264 to 266*a*, Plate CLXVI., illustrate this invention as applied to a single crossing gate, but it will be obvious that the same may be extended to double gates, and other analogous requirements, by a slight modification of the arrangements. Fig. 264 represents an elevation of a single gate, with the said locking mechanism applied thereto, Fig. 265—a sectional plan of a pair of such gates. Fig. 266—a part sectional elevation of one gate with the locking mechanism attached; and Fig. 266*a* is a detail view in connection with the latter.

A is the key bolt mounted on each gate as shewn, so as to be capable of receiving partial alternate rotary and reciprocating motion. *B* is the draw bolt working in a box situated on the post, and which is attached to the vertical rod *b* connected to a bell crank lever, and rod *c*, communicating with the operating lever placed in the signal cabin or other convenient position at the required distance. The termination of the

key bolt *A* is capable of being moved forward through a key-hole or aperture provided in the casing *C*, and into the disc-shaped piece *D*. After turning the bolt *A* partially round, a notch or recess (*d*, in disc *D*) is brought to coincide with the bolt *B*; whereupon the operator at a distance is now free to work his bolting lever, whereby the bolt *B* is forced into this notch or recess, so as to secure the bolt *A*. This last mentioned bolt cannot now be withdrawn on account of a tongue, or projection on it, no longer coinciding with the key-hole, and it cannot be turned to obtain such result, because the disc *D* is held by the bolt *B*.

When, however, the signalman returns his lever, this bolt is withdrawn, and the attendant at the gate is free to unbolt the gate, by which operation the disc is turned so that the scud bolt *B* cannot be raised, and therefore the distant controlling lever is rendered inoperative.

A spring piece *e* is preferably provided in connection with such locking apparatus, in order to prevent the disc from being turned by some other cause than the insertion of the key bolt.

At Fig. 267, we give an illustration of the means adopted by the Midland and Great Western Railway of Ireland, for operating and securing the level crossing gates employed on their line.

A and A^1 are pulleys, or drums, fixed to the heels of the gates as shown, round which an endless chain *a* is arranged to work, so as to effect a simultaneous operation of the gates. The stops *B* are all connected with the cross lever *b*, and worked by an ordinary lever (situated in a cabin or other convenient position), connected with the cross lever *b*, by the rod *c*, and bell crank *d*.

The gates themselves are worked by a winch situated by the stop lever, having a rack and pinion motion and connection *e*, the rack motion at the required distance being suitably interlocked with the point and signal levers, so as to prevent any conflicting operations.

It will be obvious that, according to this and similar arrangements of apparatus worked by chains, the drums or wheels will have to vary as the skew or angle of the crossing, as before alluded to. Thus it will be noticed that the pulleys or drums *A* at the obtuse angles of the crossing, are smaller than those at A^1 working the gates at the acute angles, it being obvious that the gates at the obtuse angles will have to travel further and quicker than those at the acute angles.

In the drawing, the gates are shown as closed against the railway, and open to the public road, and for this purpose the stops are raised in the six-footway, and depressed on the common road. The dotted arrows indicate the direction travelled by the chains in closing the gates against the road, and the full arrows, conversely, the direction travelled for closing them against the railway. The details of the mechanism for working the stops are not shown in the drawings, as it is effected by cams and balance weights in the ordinary manner.

(*To be continued*).

THE SUSPENSION CAR TRUCK.

(*Continued from page* 209.)

IN our last number we described at some length a Suspension Car Truck of American invention, which we now illustrate on Plate CLXIV.

Figs. 1 and 3 are Plans, and Figs. 2 and 4 Side Elevations of the trucks at the two ends of a car, and Fig. 5 is an End View of one of them. The lettering is the same for all views.

R is the car frame resting on bolsters *T* and *U*. Below *T* is a swivel bearing *J*, resting on one of two girders or transoms *D*. *U* resting on arch-bars *K* and *L*, with tie-bar *N*, is suspended by means of links *C*, from diagonal bars or trusses *O*, supported by, and connecting together the transoms *D*. The transoms *D* are borne at their ends by arch bars *A* and *E*, which together with tie-bar *Q*, form vertical frames outside the wheels as shewn. These frames bear on bolsters *B*, supported by springs *S*. Across the top of the axle-box *H* is a bar *I*, in bearings *i*, from the ends of which are suspended links *F*. Through these links runs a tie-bar *GG*, on the ends of which the springs *S* bear, thus taking the superincumbent weight of the whole frame and car-body. The links *C* and *F* allowing of the swinging motion alluded to in our last number.

In cars where six wheels are required instead of four, a centre pair is supplied having lateral motion only.

THE CHANNEL TUNNEL.

A VERY remarkable feature of the opposition to the Channel Tunnel is that its every phase has been an afterthought. Its inception was received with equanimity, not to say enthusiasm, and it was only after the lapse of fourteen years that the dangers which attended it became accentuated. British engineers, it was no secret, had their own views on the subject as early as 1868, and in July, 1873, according to Mr. Chamberlain — in December, 1874, by official record—the question was considered by the Board of Trade, without eliciting any idea that the construction of a tunnel could raise any question of national security. But it was raised eight or nine years later when most geological and all engineering doubts had been set at rest by means of experiments conducted at enormous private cost. And when so raised it became the subject of a lengthened enquiry, whose report was made only at the very close of an exhausting session, and is not even now in print. Nor has it had any practical result, for its conclusions are found to be so inconclusive that the whole question has been referred to a Select Committee of both Houses of Parliament, which sounds ominously like its relegation to the period of the Greek Kalends. All this, however, is according to the eternal fitness of things. The projects of the wise are always abhorrent to the minds of the ignorant, who are like the mythical toad that "ugly and venomous, carries yet a precious jewel in its head," the jewel in this case being the obstructive obstinacy which aids by popularizing that which it opposes, and enhances the ultimate triumph it has vainly sought to avert. It may prove interesting if we briefly recapitulate the circumstances attending the projection of the tunnel, and describe the earlier negotiations carried out in connection therewith.

It was towards the close of the French Exhibition of 1867 that certain French and English engineers consulted upon the subject, and in 1868 Sir John Hawkshaw, Mr. Brunlees, and Mr. Low made such examinations as were considered sufficient to demonstrate the practicability of the enterprise. Their soundings proved that the greatest depth of the sea in the Straits of Dover was less than 60 metres. The width of the Straits is 28 kilometres, the bearing of depth to width being thus as 1 in 500, presenting a gradient so inappreciable as to justify the idea of a tunnel descending by an easy slope beneath the bed of the sea, and rising, under similar conditions, on the opposite shore. The next step was to ascertain the nature of the rock forming the bed of the sea—whether it was soft enough to be easily pierced, and sufficiently dense to dispel all fear of percolation or caving in. A comparison of the cliffs on the two shores of the Straits proved that the chalky ground between Folkestone and Dover corresponded precisely, feature for feature, with the chalky mass of Cape Blanc-Nez. On either shore the silicious white chalk has for its base a thick stratum of grey marly chalk, regular in its course, free from fissures, and reposing, by a firm intermediary bed of upper green sand, upon blue clay. The geological investigations were of a very exhaustive character, and resulted in the conviction that the grey chalk formation was that through which the attempt should be made. The question whether this grey stratum is continuous across the Channel it is admitted can only be solved when the boring is complete, but the opinion of geologists is unanimously opposed to the idea of the existence of any serious fault. The level character of the bed of the sea and the adjacent formations seems to exclude the probability of any great disturbance, and sufficiently indicates that the opening of the Straits, an operation, geologically speaking, of comparatively recent date, is attributable to a simple erosion brought about by some prehistoric change in the system of the adjacent seas. Suffice it to say that a thousand engineering works have been proceeded with on much less promising geological data and carried to a successful issue.

Matters had only advanced to this point when the Franco-German war put a stop to further proceedings, and it was not till 1872 that the question was again brought prominently forward. Various new schemes appeared, some of them relating to bridges and syphon tubes, condemned as impracticable, and at the close of that year it seemed that since the ventilation of the project of Sir John Hawkshaw and his colleagues the study of the question had rather receded than advanced. But about this time Lord R. Grosvenor's Committee entered into communications with the French Government, whose Minister of Works, on August 23, 1873, directed an inquiry into the subject in the Pas de Calais. The inquiry concluded December 14, and on June 18 in the following year the Government remitted the report to a Commission composed of distinguished gentlemen, appointed to consider the communications which had taken place between France and England.

The Commission had before it evidence of a very varied and comprehensive character. There was a plan showing the levelling of the proposed submarine railway with existing lines, accompanied by one of a cutting taken transversely to the Straits, and explanatory notices. After the cutting the tunnel was to be composed of three distinct parts, the central portion being 26 kilometres in length, accessible by two inclined planes of 11 kilometres each, having a slope of from 12.5 millimetres to 13.5 millimetres in the metre. The central portion was slightly curved and separated into

two equal portions, each sloping about $0^{m}000.978$ in the metre, so as to direct their waters towards the source of the inclined planes by which it is approached. From these points proceed two drain-galleries, of diminished section, about $4\frac{1}{2}$ kilometres in length, communicating respectively with the two portions of the centre of the tunnel, bringing the waters therefrom and from the inclined planes of access to the bottom of two shafts, sunk respectively on either side, and provided with draining engines. There was also an elaborate chart of soundings showing the almost uniform depth of water, and that the superficial stratum of white clay extended across the Channel from shore to shore. The opinions of seventy-six Chambers of Commerce were obtained, and of these seventy-three were highly favourable. Nevertheless, the Commission could not bring themselves to pronounce a declaration that the scheme was one of public utility, although each member was perfectly convinced that it was so. The reasons adduced for this decision were, that the evidence submitted was insufficient to satisfy the requirements of the Ordinance of February 18th, 1834—that the scheme was still too much in embryo, and that until the continued existence of the grey chalk was conclusively proved, a platonic declaration of the utility of the tunnel would not help the projectors much. Besides, the two Governments of England and France must be consulted in order to secure diplomatic accord as to political, military, and economical considerations. The Commission took special note of certain observations presented by Mr. Low, formerly associated with Sir John Hawkshaw, but now separated from the English committee, who proposed the construction of two galleries and two tunnels. And it further was of opinion that facility should be afforded to the promoters to carry out certain preliminary works which, if pronounced sufficient to establish the practicability of the scheme, should entitle them to an eventual concession for 99 years, to date from the time when the submarine railway was open for traffic; no concession to be granted for a period of 30 years for the construction of any other submarine railway between the shores of England and France. These views were submitted to a Conseil-General, who adopted them. The reports, together with the various plans and papers, were forwarded to the Earl of Derby, then Foreign Secretary, by whom they were transmitted to the Board of Trade with the intimation "that his Lordship considers it is very desirable to support any well-considered scheme, the result of which may be to increase facility of communication between the two countries."

So far, it would seem that the *pourparlers* had been carried on in a really business like way. You do not expect any marvellous rapidity of action from Government Departments and Special Commissioners, and it is not to be supposed that the promoters thought themselves otherwise than fortunate when, having gone through the whole French ordeal, they succeeded in two years in being placed in authoritative communication with the English Board of Trade. They had, besides, got backed by a not unfavourable sentence from a Foreign Secretary generally credited with a disinclination to soar into the regions of sentimental ecstacy, and the Board of Trade must have seemed an insignificant obstacle after all the difficulties already surmounted. Mr. Farrer did not reply in a very promising way. He pointed out certain initial difficulties, as, for instance, that the nature of arrangements on opposite sides of the Channel would be of a totally different character. Here, the Company had given notice of a Bill to enable them to acquire the land—in France they sought a concession. So that in England the relations of the Government to the Company would be peculiar—the former would be bound by no concession, the latter by no conditions. Therefore, it was suggested that it would be expedient, if not necessary, for Government to decide, "before the Bill in question passes, whether it is desirable to make any and what terms with the promoters." He announced that the Board of Trade had no doubt of the utility of the work if successfully completed. As to the physical possibility or probability of completing it they offered no opinion, but they thought it ought not to be opposed "so long as the English Government is not asked to make any gift, loan, or guarantee." They did not take a sanguine view of the prospect of obtaining an adequate income from the traffic, looking to the large sum required, and the competition by sea, but this they recognize, "so long as the Government is not asked for money, as a matter for the promoters rather than them." Reference having been made to the military necessities of either country, Mr. Farrer observed that "this is a question for the War Office rather than the Board of Trade. But it is clear that Her Majesty's Government must retain absolute power not only to erect and maintain such works at the English mouth of the tunnel as they may deem expedient, but also, when they apprehend danger of war, or of intended war, to stop traffic through the tunnel. And it is for consideration whether they should not have the right to exercise this power without claim for compensation."

It will thus be seen that, notwithstanding the denial of Mr. Chamberlain in Parliament on the 15th August, 1882, "the question of national security" had been abundantly present, though not "raised" in the sense of opposition to the Tunnel, to the mind of his present Permanent Under-Secretary in 1874.

Certain matters of detail were sanctioned with modifications. The monopoly was agreed to with the condition that the route should be opened within a specified time. The determination of the tariff of charges was postponed, perfect freedom of action to both Governments being distinctly reserved. And it was pointed out, as it had been by the French Commission, that, as it seemed to be intended that there should be two companies, an English Company on the English side and a French Company on

the French side, it did not appear how the two companies were to work together, or where their respective properties, powers, and liabilities were to end. The letter of the Board of Trade was, in a paraphrased form, reproduced by the Foreign Secretary and despatched to the Count de Jarnac, the French Ambassador in London.

The preliminary works proposed to be undertaken by the Sub-Marine Tunnel Company in French territory consisted of—

1. A shaft of about 6 metres diameter and 133 metres in depth, sunk on the sea-shore between Calais and Sangatte on the site of the boring performed by the English engineers, Sir John Hawkshaw and Mr. Brunlees, the authors of the project.

2. A circular drain gallery, lined with masonry 2.10 metres in diameter, running from the bottom of the shaft and extending a distance of at least one kilometre beneath the sea. This gallery was intended to drain the waters of infiltration from the tunnel.

As the shaft will penetrate, at a depth of about 25 metres, alluvial soil, beds of gravel and sand, it will be surrounded with a cast tubbing having at its base a crown-work of plates of sheet iron riveted together, the edges of the lower plates being bevelled to facilitate their penetration into the soil.

When this crown-work reaches a limestone bed of such consistency as to resist the influx of too great an amount of water, the shaft will be lined with bricks and Portland cement.

3. The bottom of the shaft will act as a reservoir for the waters of infiltration of the tunnel, which will be raised to the surface by means of draining machines.

The drainage-gallery will be excavated by the Bruton or other engine, and will be lined with bricks and Portland cement.

During the excavation of the shaft and gallery, the exploration of the bed of the Straits commenced by Sir John Hawkshaw will be continued. The continuity of the white chalk having been proved, efforts will be made to fix the level of the bed of upper green sand before mentioned, the continuity of which would constitute positive proof of the absence of any dislocation in the bank of grey chalk through which the tunnel must be driven.

These preliminary works, it was considered, would give data upon which an approximate estimate could be made of the cost of the tunnel, and of its junction with the existing railway systems of France and England.

It will thus be seen that, notwithstanding considerable and unavoidable delays, appreciable progress was being made with the idea. On all sides there was a sincere desire that the practicability or otherwise of so great a work should be satisfactorily demonstrated, and a perfect unanimity of opinion as to its great utility. The negotiations were conducted in the most practical and businesslike manner, and each party showed, and had good reason to feel, the utmost confidence in everyone with whom the details brought him in contact. True, all parties saw certain difficulties, physical and otherwise, but these were mentioned in no captious spirit, but with the sincere hope that means might be devised for overcoming them. Thus, while the French Government declined to grant a concession for 99 years, with a monopoly for 30 years, in favour of a project that it was possible might end in moonshine, they very readily granted permission to those interested to make experiments to determine whether the work could be carried out or not. More than this, they gave the promoters a certain amount of countenance. They publicly recognized the magnanimity with which the scheme had been conceived, and dwelt in their report upon the high character of those who had taken it in hand. At the same time that they pointed out that the existence of a fault in the bed of grey chalk would prove absolutely fatal to the project, and that the moment of its discovery must witness the absolute loss of every shilling hitherto expended on the works, they recognized graciously that, however great the difficulties with which such men had to contend, their resources would always be equal to the occasion so long as they were one step on the right side of the impossible. And while enumerating, as was their duty, some of the obstacles to success, they affirmed that such should not be hypercritically invoked to act as hindrances to the accomplishment of a work whose utility had now been placed beyond all possibility of doubt.

Thus, although the promoters had not obtained quite all they wished, they had met with no discouragement. Frenchmen conduct matters with a dignified courtesy nearly allied to sentiment itself. Our engineers had besides had to deal with men of science of their own class, the Commission consisting of four Inspectors-General of Roads and Bridges, an Admiral, an Inspector-General and an Engineer of Mines, and a Hydrographical Engineer. When they crossed the water, however, they found themselves in a very different moral atmosphere. We are a nation of shopkeepers. Our Board is that of Trade, and Mr. Farrer is its Prophet. Diplomatic etiquette brought the report of the French Commission to Lord Derby, and official custom handed it over to Mr. Farrer. The former, who was about this period reading deprecatory lectures to bucolic audiences against the "gospel of getting on" in the case of individuals, did not apply his rest-and-be-thankful theories to national undertakings, backed by associated capital and fathered by eminent men of science. He rather went out of his way to recommend the scheme to the Board of Trade in the words we have quoted above. But, as we have seen, the judicial mind of Mr. Farrer approached it with a very different bias. He commenced a long, and undoubtedly an able reply, by confessing the utility of the work, and concluded by saying that, subject to the observations (given in an earlier page) the Board of Trade saw no reason why Lord

Derby should not approve the course proposed by the French Government. An examination of those observations will show that they contain much that is discouraging to the promoters in the mercantile aspect of their undertaking, and more than one suggestion calculated to make them exceedingly dubious as to the likelihood of the dual company working in harmonious accord. And although, as we have remarked, Mr. Chamberlain now tells us that there was not at that time any idea that the construction of the tunnel involved any question of national security; it is plain from Mr. Farrer's words that the subject had been looked at from that point of view — that such a contingency had been considered, and that the Board of Trade was satisfied that such danger could be neutralized by "Her Majesty's Government retaining absolute power not only to erect and maintain such works at the English mouth of the tunnel as they may deem expedient, but also when they apprehend danger of war, or of intended war, to stop traffic throughout the tunnel." These are the powers, and all the powers, demanded by Mr. Farrer on behalf of the Government, and all reasonable men will deem them amply sufficient. As to the manner in which they should be exercised, he adds, "This is a question for the War Office rather than the Board of Trade." Just so. The War Office is an Executive Department, competent to advise on matters of offence and defence, but possessing no power of initiative. It is reasonable to suppose that the words we have quoted emanated from the War Office in reply to a question put to them by Mr. Farrer, and that, therefore, the possibility of national danger had been considered in the sense of providing against it. If we are correct in this surmise, the hollowness of the opposition raised against the construction of the tunnel during the past year is at once manifest. No one has ever doubted that the tunnel might, under some extremely improbable circumstances, be captured by and made the means of introducing an invading army. But eight years ago, the Permanent Secretary to the Board of Trade wrote officially to the Foreign Minister, indicating the general means by which such danger could be made no danger at all. This is the simple position taken up by the tunnel advocates and buttressed by the official opinion of so high and responsible an authority, written after more than a month's deliberation, it seems to us as impregnable as the everlasting hills.

The march of modern thought has taught us many things, and amongst these not the least important is to look at every subject from two points of view—our own and that of other people. This military phase of the present question is one we have no desire to blink, and we are far from denying to the military authorities the right to express themselves upon it. But the public have also the right to examine and form their own opinions upon the oracular utterances of professional specialists, more particularly when they happen to be in direct opposition to measures calculated to promote the interests of progress and to contribute to the welfare of mankind. All history, ancient and modern, shows that nothing has tended so much to produce national prosperity as international communication, and at this moment the true source of England's wealth is its pre-eminence as the great carrying power of the world. A prominent illustration of this is presented by the existing condition of affairs in Egypt, where the action of England, high-handed as it appears to some, is recognized by the greatest foreign statesmen as just and right, because our interests in that country are represented by 85 per cent. of the entire traffic which passes through the Canal. At this moment our naval and military forces are defending the commercial interests upon which the greatness of our country rests, and, suppose the existence of a Channel Tunnel and the outbreak of war, they would only have to do on their native soil what they are now doing in the less fortunate land of the Pharaohs. The mission of our armaments is to protect civilization, not to retard it, and the question of expense is a bagatelle. No statesman worth his salt can stand up in the House of Commons and say that a project calculated to facilitate the operations of commerce is to be arrested because some carpet-soldier is under the hallucination that its protection will cost a sum which the country will not cheerfully pay. We already spend nearly 30 millions a year in the protection of our enormous trade. It has been estimated—very roughly, we should imagine—that adequate works at the tunnel's mouth would cost a matter of three millions. Suppose they did, what is that in comparison with the extraordinary impetus which would be given to outward and inward foreign trade and travel? If trade is to cease because our military authorities decline the responsibility of defending it, we had better sell our ironclads, unlink our new battalions, and relegate our regiments to the localities from which—*lucus a non lucendo*—they take their new-fangled names.

We have described the origin of the movement and shown that success is geologically probable. Of the capacity of engineering science to construct the works in the absence of insuperable natural obstacles none of our readers will entertain the smallest doubt. And if no obstacles are interposed by nature, man must not be allowed to invent any. It is not possible that international difficulties can arise of such dimensions as to be beyond the power of diplomacy to provide for, and the grisly phantom of national danger must be exorcised by the military authorities. The administration of the line must be conducted under the same conditions of prudence and common sense as bring other colossal undertakings to a successful issue. At present the relations of both parties are most cordial. If the French claim that the idea is theirs, they frankly admit that the labours of Englishmen have shown its feasibility, while every official of both countries to whom the project has been submitted

proclaims its undoubted utility. What is useful in these days is necessary, and what is necessary has to be done. At present the available statistics are few, but the traffic returns of Calais, Boulogne, Havre and Dieppe showed that in the single year 1869, three hundred and fifty thousand Channel passengers passed through those four ports, and the estimated increase since that period has been at the rate of 5 per cent. per annum. This is sufficient to neutralize, if not to entirely dispel, some of the doubts which might be raised by Mr. Farrer's reluctance to take a sanguine view of the remunerative character of the scheme. Permanent Under-Secretaries, from the very nature of their functions, must always be pessimists. Success brings them neither glory or profit, while an unfulfilled prediction would spell disgrace. Besides, they are perpetually bored with chimerical schemes, and naturally look upon each presented to them with an eye of suspicion and a disposition to disparage. The best scheme ever invented is capable of being met by objections bearing some sort of a reasonable appearance, and the prudent official saves his own reputation by pointing these out and giving what virtually amounts to no opinion at all. If the thing succeeds, he is very happy —if it fails, he says, "I told you so." The competition by sea, for example, upon which Mr. Farrer lays some stress as reducing the probability of dividend earning by the Tunnel Company, is very easily answered. Both the London, Chatham, and Dover, and South Eastern Companies would be in direct junction with the Tunnel Railway, so that the latter would practically abolish opposition by sea on the Boulogne and Calais routes, or, what is infinitely more probable, the new facilities and comforts would so greatly increase the number of travellers, and so much reduce the freight of merchandise, that all would be more or less prosperous. Such has been the case in London. The creation of our splendid system of subterranean railways has not brought about the destruction, or even caused injury, so far as we know, to the interests, of the proprietors of cabs, omnibuses, or penny boats, any more than the inventions of Hargreaves and Arkwright have wrought ruin to the operative class. Our fervid civilization is ever hungering for the aliment of science, but pays ungrudgingly for the gratification of its appetite.

In this paper we have dwelt mainly upon the proceedings of the remote past, answering such criticisms as cropped up in the course of events. The sensational circumstances of recent date will be clearly in the minds of our readers, though we may hazard a doubt whether any of them are sufficiently informed to come to a decided opinion upon them. The main question has been utterly begged, and the demeanour of "the attorney on the other side" looked suspiciously as if, having no case, he had decided to earn his fee by abusing his opponent. In our next number we propose to discuss the latter-day aspect of affairs, amongst others the preposterous charge of breach of faith, which when examined, we shrewdly suspect will prove to have been the accomplishment of a portion of the work indispensable to the safety of those engaged in it, and entirely justified by the undertaking given. In the meantime, we shall be in possession of the latest official deliverances on the subject. Then a patient universe may await with all possible equanimity the conclusions of the Committee of both Houses. When the average Englishman finds his project relegated to that limbo he generally turns his attention to the pursuit of some other path of industry without wasting time in vain laments over his blighted hopes and buried aspirations. These tribunals are distinguished equally by the high impartiality and wisdom of their decisions and the length of time they take in arriving at them. When Sir Edward Watkin congratulated his shareholders upon the fact that the Channel Tunnel scheme was to be submitted to a private Committee of both Houses of Parliament, he based his joy only upon the belief that there was no fear that such a tribunal would be biassed by international prejudice, but we do not observe that he ventured to predict the date at which their fiat would go forth. For the past eight years vast stores of scientific and other evidence have been and are still in process of accumulation, and opinions have been gathered from pretty nearly every department, profession, and interest in both the countries immediately concerned. A deplorable amount of prejudice has been imported into the question, engendered, in some cases at least, by professional jealousy and official pique. The names of the mighty dead have been invoked on one side; our "only general" sneers at "speculative capitalists" on the other, and the irresistible arm of the law has interposed to prevent the prosecution of an enterprise which is recognized by those most capable of judging as desirable in the best interests of humanity. It is from this chaos that the Committee have to evolve a conclusion from which there will practically be no appeal, and our greatest trust lies in the fierce light which public feeling throws upon the question. That feeling is now so highly wrought that every particle of evidence adduced will be watched with eager vigilance, and unnecessary delay resented with an increase of the righteous indignation already aroused by the factious opposition which has so far hampered the progress of this important and popular work.

THE WALDUMER BRAKE.

A SERIES of exhibits of a new device known as the Waldumer Electro-Magnetic Brake have been recently held on the New York, Woodhaven & Rockaway Railroad, at Rockaway Beach, Long Island, in which electricity is used as the actuating and controlling medium.

The system, says the *Railway Review*, consists of a dynamo-electric generator, coupled with and driven by a small rotary engine of an improved pattern, both of which, on the same bedplate, are mounted on the running board of the locomotive just forward of the cab. The rotary receives its supply of steam from the locomotive boiler, and is controlled by the ordinary throttle-valve. The mains conducting the electric current extend from the dynamo throughout the length of the train, in parallel lines, the system of circuiting being that known as the "multiple arc," by which the interruption of current on one car affects no other car of the train.

They consist of non-insulated copper wire, and are divided into car lengths and fastened under the bodies. These separate lengths have as terminals flexible conductors of copper wire cable surrounded by rubber tubing, imparting to the whole much the same appearance, though in decreased dimensions, as the flexible terminals in the air-brake systems.

For electric connectors or couplings, a dovetail tongue and groove device is used, each member of the coupling having both tongue and groove, thereby insuring perfect connection under all circumstances. A flat spring, through which the tongue projects, maintains perfect contact, takes up all wear and binds all parts sufficiently to prevent separation from any cause, except a strong direct pull resulting from the separation of the car from the balance of the train, in which event the uncoupling is automatic, the whole coupling being cheap, durable, and reliable.

From the mains, branch wires extend to brass strips or springs in contact with two brass discs fixed upon, but insulated from, the axle and from each other. They serve to conduct the current from stationary wires to the brake device itself, which consists of a three-flanged, spool-shaped electro magnet, a part of and revolving with the axle. Its dimensions are four by fifteen inches, and it is wrapped with four layers of No. 8 wire in the same manner as thread is spooled, with the exception that the wire is wrapped in one of the spaces in a direction contrary to that of the other. This has the effect of concentrating the magnetic force where it is wanted, instead of directing it to the extremities of the axle.

The electro-magnet has for an armature nine square wrought iron bars, one inch by sixteen inches in size, which are used as delivered from the mill without finish of any kind. These extend over the three poles of the electro-magnet, to whose though the magnet continues to revolve. It is in fact a cylindrical form they adjust themselves, and have their ends engaged in slots in the heads of the drum surrounding the whole. A false head, dust proof, covers these ends, keeps the bars in place, and also serves to hold a circular spring, keeping them normally out of contact with the magnet and preventing unnecessary wear. A chair is fastened to and extends from the drum just described to a grooved or windlass wheel, which takes the place of the hand wheel in the hand-brake. From the shaft of this wheel another chain extends to the ordinary brake lever. This device in no way interferes with the hand-brake, which is indispensable in making up trains, &c. In order that the brake may be set with the minimum of initial motion, and at the same time obtaining the maximum leverage, a "take-up," in the form of a half eccentric, is made part of the wheel, and is grooved to receive the chain connecting with the lever, so that instead of requiring three revolutions of the grooved wheel to take up the necessary motion on the shaft, it is done in a half turn. This is possible in braking, because much motion and very little power are required to bring the shoes to the wheels and much power with scarcely any motion after that. The gross leverage in the system is $^{72}/_{4} \times {}^{29}/_{4} = 104{\cdot}4$ to one; allowance to be made for friction in two fulcrums.

To operate the brake it is only necessary for the engineer to open the throttle-valve of the rotary engine to the degree required, the amount and strength of current depending directly upon the speed of the engine and dynamo. The amount of current with which the magnet of each brake is charged is indicated upon the electric gauge, which is equivalent in appearance and action to the ordinary pressure gauge. The current instantly traverses the length of the mains, whose electric resistance is practically nothing, and distributes itself equally to all the magnets, the resistances of which are equal (0·6 ohm), thereby exerting an equal and uniform force throughout the length of the train. The effect of the circulation of the current through the wire surrounding the core of the magnet is to make the periphery of the iron flanges magnetic, causing the bars to be attracted, and to adhere to them with a force proportional to the square of the current.

As the magnet revolves with the axle, the bars and consequently the drum, in the heads of which their ends are engaged, revolve with it until the brake shoes are brought against the wheels, where they are held as powerfully as may be desired, though the whole system may be instantly released or the pressure decreased by closing the throttle valve. When the shoes are hard against the wheels, the motion of the drum ceases, and it is simply held in place,

frictional appliance in which the friction is applied and regulated by the electric current. Its economy in the consumption of current consists mainly in the facts that it neither creates motion nor power, but simply transmits as much of both as may be required to do the work under different circumstances from the revolving axle to the ordinary brake mechanism, having no inertia to overcome. It has also the advantage of contact between armature and magnet, an item of importance when it is considered that the power of the latter varies inversely as the square of the distance between it and the former.

In the exhibits at Rockaway Beach referred to, the train consisted of a 40-ton engine, a 20-ton tender, four empty box freight cars of about 10 tons each and a 20-ton passenger coach. The only brakes applied were those on the four empty freight cars, yet the entire train was under perfect control, stops at stations being made accurately at varying rates of speed up to 30 miles per hour. At the latter rate stops were made in twice the length of the train. When travelling at the same rate, the coupling pin of the last car was pulled and the brake automatically set, stopping the car within a distance of about 60 feet. This automatic part of the device is placed in passenger service under each coach and can be instantly released by throwing a switch. In freight service it is in the caboose, and in the event of the separation of the train, the engineer controls the forward part and the conductor the separated portion, to both of whom the separation is announced by an electric gong. The advantages claimed for the Waldumer brake over all others are:

Its cheapness, simplicity and durability; that its operation is in no way affected by the condition of the weather, operating as well in winter as in summer; that it is economical to operate, as the cost of generation of the current is insignificant, no steam being used, except when the locomotive engine is not using it; that it has no leakage in conductors and requires no air-tight fittings, besides having only one valve, and that in the supply pipe for the engine; that it can be applied to trains of any length, including the longest freight trains; that it will do better work without sliding wheels; that it can be more readily and rapidly applied and released.

WHITE'S FOG SIGNALS.

THE object of this invention is to give an engine driver notice of the state of the signals, in foggy weather, when they are invisible, by sounding a gong fixed on the engine itself.

We illustrate this apparatus on plate CLXVI., Figs. *A* and *B*.

In the centre, or through the foot-board of the engine, their runs a vertical double rod *a a*, carrying a roller *c* at its lower end. On the ground between the two lines of rails, are mounted two inclines *b*, *b*. These, when the gong *d* on a passing engine it is to be sounded, are brought into position *centrally* between the rails, so that the roller *c* may strike on them, and running up them raise the rod *a a*. On the upper end of the rod *a a* is a spiral spring *g*, resting across the top of which is a lever or hammer *j*, pivotted at *k*. The effect of the rod *a a* being raised, is to cause the hammer *j j*, through the intervention of the spring *g*, to strike the gong *d*. Another spring *h*, fixed above, forces the hammer and rod *a a* down again to their normal position, as shown in the drawings. This spring *h* also serves as a buffer to arrest the momentum of the rod *a a* when suddenly moved upwards by the action of the roller on the inclines.

These inclines *b b* may be brought to and from a central position, by making the blocks on which they are formed slide upon rods *i i*, fixed horizontally, and at right angles to the rails: such movement being given them by means of a rod *l* and bell crank lever *m*, connected to a lever in the Signal Box by means of a rod *r*. So that by the movement of this lever in the Box, the inclines may be moved in or out of action, as the signal man deem necessary according to the state of the weather.

Three separate inclines are provided for each signal box, one for the distant, and two for the home signal.

BRAKES.

THE usual half yearly Blue Book has been issued giving the returns of the operation of the various brakes in use by the respective Railway companies. These we append, and, as they speak for themselves, little comment is necessary. It may perhaps appear that they are neither quite complete or altogether satisfactory. The enormous discrepancies would seem to indicate a presence of partiality in some quarters, and it is understood that they do not command confidence as possessing undoubted practical value.

The mileage and faults of the WESTINGHOUSE BRAKE are returned as follows:—Great Eastern Railway,

1,129,964 miles, 83 faults; Great Northern, 18,317 miles; Lancashire and Yorkshire, no mileage return, 10 faults; London and South Western Railway, 20,204½ miles, 1 fault; London, Brighton and South Coast, 2,679,483 miles, 93 faults (continuous automatic air); London, Chatham and Dover (continuous automatic air) 132,768 miles, 11 faults; Metropolitan, 472,992 miles (air pressure) Midland (automatic air) 354,207 miles, 40 faults; North Eastern, 3,386,370 miles (automatic) 54 faults; Rhymney 40,980 miles; West Lancashire, 25,182; Caledonian, 502,642 miles (automatic) 36 faults; Glasgow and South Western, 374,493 miles (continuous automatic air) 30 faults; North British, 1,169,649 miles (continuous automatic air) 75 faults. Total 10,307,251½ miles, 1 fault in 2,397 miles.

The Vacuum Brake.—Great Northern Railway (vacuum), 3,451,605 miles, 34 faults: Automatic vacuum, 28,487 miles 1 fault; Great Western Railway (automatic vacuum), 2,022,799 miles, 22 faults; London and North Western Railway (vacuum), 8,712 miles. Total 5,511,603 miles, 1 fault in 98,788 miles.

Sanders and Bolitho's Brake.—The Midland Railway, 3,695,831 miles, 9 faults; 1 fault in 410,648.

Smith's Vaccuum.—The Great Eastern Railway, 128,492 miles, 1 fault; Great Western, 114,405, 1 fault; London and South Western, 22,201 miles, and automatic 25,746 miles, 2 faults; London, Chatham and Dover, 17,658 miles, 1 fault; Manchester, Sheffield and Lincoln, 1,340,724 miles, 5 faults; Manchester South Junction, 94,350 miles, 2 faults; Metropolitan, 742,023 miles; Midland, 139,694 miles; North Eastern Railway, 349,575 miles, 5 faults; South Eastern Railway, 473,492 miles, 1 fault; Taff Vale, 95,797 miles and 11,987 miles automatic; Ballymena and Larne, 8,825; Dublin, Wicklow, &c., 4,080 miles, and 8,256 miles automatic; Great Northern of Ireland, 36,580 miles automatic; Great South and West, 776,625 miles, 1 fault; total, 4,400,513 miles; 1 fault in 231,606 miles.

Clark and Webb's Brake.—London and North Western Railway, 7,575,426 miles, 20 faults; London, Tilbury and Southend, 1,569 miles, North London, 846,100 miles, 8 faults; Caledonian, 408,845 miles, 16 faults; Belfast Central, 11,160 miles.

The number of locomotive engines and tenders used for passenger service, and fitted with continuous brakes during the above period was 2,773; the number of passenger carriages 20,366; and the number of other vehicles fitted with continuous brakes was 7,453. The number of locomotives not fitted with continuous brakes was 2,622; and the number of passenger and other carriages used for passenger trains not fitted with continuous brakes was 17,727. Smith's vacuum is the brake which appears to be in most general use, but the Westinghouse automatic brake, though in use by a less number of companies, is applied to a greater number of vehicles. Clark and Webb's brake, though used by fewer companies, is in proportion more extensively applied, the London and North-Western Company alone applying it to 5,609 carriages. Sanders and Bolitho's automatic vacuum, and Smith's automatic vacuum, are extensively adopted.

THE BLUFF CITY RAILWAY INCLINED PLANE, AT NATCHEZ, MISS.

THIS inclined plane is designed to elevate and lower freight from the city, situated upon a bluff on the eastern bank of the Mississippi River, to the river itself—the tracks of the incline running east and west.

The conditions for working and the data are thus given by the *American Engineer*:

Net load to be raised, 15 tons; this to consist of a loaded narrow gauge freight car, which is to be run upon the platform cars of the incline. Length of Plane, 836 3-10 feet. Average speed of platform cars, 5 miles per hour. Angle of plane, 1 in 5, except at lower end, when for a short distance it is nearly 1 in 4. Platform cars, 38 feet long, 10 feet 6 inches wide, in clear.

The location of the plane is such that its lower end terminates in the river, the cars descending against a wharf-boat. As the river rises and falls about 40 feet maximum), the length of the incline is lengthened or shortened about 200 feet according to the state of the tide in the river. To provide for this, special arrangements are made for adjusting the length of the ropes to correspond with the working length of the plane.

The general arrangement of machinery is as follows:

The incline consists of a double track lines of rails, 6 feet gauge, the tracks being 12 feet centre to centre. Upon each track there is a platform car attached by two wire ropes to separate 10-foot drums at the head of the incline, and at right angles to the track. These drums are fixed upon the same shaft. The ropes from one car are wrapped *over* its drum, while those from the other are wrapped *under* the other drum; thus as the drums revolve, the ropes on one are wound up, while on the other they are being unwound, one car ascending as the other descends, an arrangement common to most inclined planes, and one possessing the advantage of one car balancing the other, and so doing away with the necessary power to lift the cars themselves.

Between the drum, and forming part of them, are two

spur-mortice gears, a bearing for the shaft being placed between them, and these are driven by two iron pinions (shrouded) upon the engine shaft. The engines are double, fitted with the ordinary locomotive reverse motion, and are situated behind the drums; they are controlled by the Engineer, in the cab, by levers and rods. As the incline is not running continually or even for a long period at a time, the boiler is therefore much smaller than is usual for engines of this size. The boiler for these engines is situated in front of the drums, close beside the wall of the basement, in which the machinery is located.

In front of the drums are placed the rope guides, one for each drum, the object of which is to guide the ropes evenly upon the drums, in order to prevent the ropes over-riding each other, as well as to space the wraps around the drum so that the sides of the ropes will not touch, and thus reduces the wear upon them. Each guide consists of two frames carrying a screw, upon which two sheaves turn, one for each rope, the sheaves revolving independently of the screw; but they are arranged to move horizontally by it, the screw being proportioned so that when the drum has revolved once the screw has moved the sheaves horizontally a distance equal to the space occupied by one wrap of the rope on the drum. The screws are driven from the drums by means of shafts and gears.

Each drum is fitted with a brake operated by the engineer in the cab. Around each drum is placed a turned ring, bolted to the lagging of which the drums are built, and around this ring the brake straps of Otis steel are bent. The straps are lined with maple blocks which rub against the ring. For adjusting the ropes for varying length of incline, the following expedient has been adopted. One of the drums, the south drum in this case, is not keyed fast to the drum shaft as the other, but runs loose upon it. On the south mortice gear is cast a flange 8 feet in diameter, similar to the brake ring around the drums. In addition to this there is, inside of the south drum and at its southern end, a heavy 8-foot brake spider keyed firmly to the shaft. The drum entirely surrounds the spider and the flange which projects from the side of the mortice gear. Around the spider and the flange pass heavy brake straps connected to the drum, where by an arrangement of compound levers and a screw, the straps can be firmly tightened. This forms a friction clamp between the drum and the spiders keyed to the shaft, and the drum can therefore be made fast or loose upon it.

By this device the south drum can can be disconnected from the shaft and other drum, allowing the north drum to wind or unwind, independently, enough rope to suit the length of incline, when the other drum is clamped to shaft and is worked as before.

The platform cars are framed of wood and have tracks laid upon them of 3-foot gauge, for the narrow-gauge freight cars they are designed to carry. The running gear, axles, truck wheels, boxes, etc., are made according to the master car builders' standard, there being eight wheels to each car.

The attachment of the ropes to the car is made through an equalizing bar, so that an equal tension may be maintained in each rope.

The important dimensions of the machinery are as follows:

Boiler.—48 inches diameter, 22 feet long, five 11-inch flues.

Engines.—Two 14 inches diameter, 24 inches stroke.

Pinions.—Two $3\frac{1}{2}$ inches pitch, 9 inches face, 21 cogs, $23\frac{3}{8}$ inches pitch diameter.

Mortice Wheels.—Two $3\frac{1}{2}$ inches pitch, 9 inches face, 147 cogs, 13 feet $7\frac{5}{8}$ inches pitch diameter.

Drums.—Two 10 feet diameter.

Drum Shaft.—9 inches diameter, 23 feet long.

Ropes.—Four $1\frac{1}{4}$ inches steel, (Roebling) 1,000 feet long.

COKE AS FUEL FOR THE LOCOMOTIVE.

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IN an effort to comply with the requirements of the "smoke ordinance" of Chicago, some of the leading railroads have made an endeavour to use coke as fuel. The absence of the foul clouds of smoke and the extra cleanliness about the rolling stock attached to them, bore witness to the good qualities of the fuel as non-productive of the prohibited nuisance, but according to reports the coke failed to make the necessary steam, and so what ought to have proved a boon, must be discarded. The Chicago *Tribune* gave the following remarks on coke burning:—

"The use of coke in furnaces of locomotives designed to burn bituminous coal presents many difficulties which have not been successfully overcome. A bituminous coal burning engine requires a furnace of but moderate size, with grates having comparatively small area of opening. In ordinary practice a fire not exceeding five inches in depth will generate steam freely. Direct contact of incandescent coal with the furnace-sheets of the boilers is not relied upon for the generation of steam. The space of a locomotive furnace occupied by the bed of fire forms but one-twelfth of the capacity of the furnace; the other eleven-twelfths above the fire constitute a combustion chamber, where gases arising from the coal ignite, evolving a great amount of heat, communicated to the boiler by the furnace sheets and flues through which the gases pass in their escape to the atmosphere. When attempts have been made to use coke in the furnaces of coal-burning engines it

has been found that steam could not be generated in sufficient quantities to meet the requirements of ordinary service. Coke being a product of combustion resulting from the extraction of gas from bituminous coal, it possesses but a small part of its original value for the purpose of generating steam in locomotives. To overcome this deficiency in heating power a much greater quantity of coke must be used, and this is where practical difficulties are experienced. To produce perfect combustion requires free admission of air through the fire. Under the impulse of a heavy exhaust, a strong current of air readily passes through a coal fire, and no difficulty is experienced with the draught; but where the air has to be drawn through a bed of incandescent coke from twenty to twenty-four inches in depth, the draught is so far impeded that the engine will not make steam, and the experiment at once becomes a failure. If the amount of coke on the grates is reduced to admit of a free draught, there is then an insufficient amount of heat to generate steam and failure to gain results. It can be readily seen that an attempt to substitute coke for coal in a coal-burning engine is impracticable.

"The question then arises whether the furnace of a locomotive boiler can be enlarged to an extent sufficient to properly burn coke. The points limiting an enlargement of a locomotive furnace are the gauge of track and the spread or distance apart of the drivers. The gauge of track being fixed at 4 feet 8½ inches, the greatest width of furnace obtainable on the standard American pattern of engine is 36 inches. The spread of the drivers is limited by curvature of the track, and in American practice the spread has been generally fixed at 8 feet. Within this space the largest dimensions obtainable for furnaces are 3 feet by 5½ feet, giving an area of 16½ feet. From experiments made with coke, it has been found, as compared with coal, that four times a greater quantity in bulk is required, which would make it necessary to enlarge the furnace considerably. The width being limited to 3 feet, the furnace would have to be made much longer to obtain the desired area; and within the limits specified space cannot be obtained for the extension.

"It is not considered impossible to construct a type of engine in which coke could be successfully used as fuel, but the conditions would require a radical departure from established forms of construction and necessitate many costly experiments. In connection with the general use of coke there would be many minor matters requiring attention, such as adequate facilities for handling large quantities quickly in unloading from cars and loading on tenders, the providing of large storage houses to protect it from rain, also the housing over of the tenders for the same purpose."

OFFICIAL REPORTS ON RECENT ACCIDENTS.

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Major Marindin has reported the result of his inquiry into the causes of an accident which occurred on the 6th September last, near Stamford, on the Great Northern Railway. This accident, which was fortunately unattended by any casualties. was clearly due to the driver of the train running at an excessive rate of speed, considering the class of engine he was driving, and the nature of the permanent way, which, although in very fair order, is not of a type suited for high rates of speed. The trains are so timed that there can be no necessity for a speed of over 30 miles an hour; whereas, in this case, looking at the fact that the Great Northern train, running at not over twelve miles an hour when passed at the junction by a Midland train, running at between thirty-five and forty miles an hour, had nearly caught up this Midland train when the accident happened, 1¼ miles from the junction, it is probable that the speed was over fifty miles an hour when the accident happened. The distance run by the train after the engine left the rails, and after the vacuum brake was applied, was over 320 yards, and this fact also shows that the speed must have been high. It appears that this driver has the reputation of being a rash driver, and that complaints have before been made that he drove too fast, and raced the Midland trains, as he was evidently doing upon this occasion, and it is much to be regretted that those in authority to whom those reports were made, viz., the station masters at Stamford and Barnack, and the leading driver at Stamford, did not take steps to put a stop to this racing before it led to an accident. It is to this, far too common practice of leaving faults unchecked and breaches of rules unnoticed, so long as things go on smoothly, that the causes of a very large number of accidents may be traced.

Major Marindin has also reported the result of his inquiry into the causes of an accident which occurred on the 10th of July last, at Ringwood station, on the London and South-Western Railway. This slight accident was caused by the signalman moving the points of the main line cross-over road, which were at the time facing points, while the Bournemouth train, backing along the down main line to the platform, was passing over them, and so splitting the train, the three leading vehicles having already passed the points and remaining on the rails, the other two being thrown off the rails, and the engine being turned on to the cross-over road. The man is an old and careful servant, bearing an excel-

lent character, and he at once frankly admitted his mistake, stating that he was anxious to make the road right for getting a goods train, which was waiting on the branch, across on to the up main line, and so clearing the branch for the Bournemouth train to start as soon as it was made up. The driver seems to have been running cautiously and to have been prompt in stopping his train. The accident could not have been caused by any action of the signalman if the points had been fitted with proper facing point appliances, and I trust that no time will be lost in providing them, seeing that these points are facing points to all trains running in the regular course to the up-platform, as well as to all trains being backed along the main line. It is clear that the practice of passengers taking their seats in the branch train before it can be drawn forward out of the bay line has been countenanced, and, unless it can be stopped, the guard should always accompany the train, and a signal should be provided, interlocked with the points and facing point bolt, to signal the trains back along the down main line.

Major Marindin has also reported the result of his inquiry into the causes of the collision which occurred on the 16th July last, between B. and C. signal-boxes, Waterloo, on the London and South-Western Railway, This collision was due to a mistake in the block working between C. and B. signal-boxes, Waterloo; and it is clear from the evidence that the mistake was made in the former signal-box. The 6.45 up Portsmouth train, which was running about 16 minutes late, was stopped at the B. signal-box home-signal on account of the line at Waterloo being obstructed by some shunting of empty passenger trains, of which there were more than usual, owing to the large traffic to Wimbledon Volunteer Encampment. The signalman in B. box states that he did not give "Line clear" to C. box after the arrival of this train, and that he did not lower the electric signal in C. box; and his evidence is corroborated by that of the booking boy in his box. The signalman in C. box, although he says that he thought the line was cleared when he lowered his signals for the special train from Wimbledon, is evidently not at all certain that such was the case; while his booking boy acknowledges that he did not see the electric signal lowered, or hear the two beats of the bell for "Line clear," although he entered "Line clear" in his book. It is evident, therefore, that the collision was caused by great carelessness on the part of the signalman in C. box, in taking off his signals for the Wimbledon train before the line had been cleared from B. box, and with the tail lamps of the preceding train well within his view, only 310 yards distant from him. The booking boy in the box is also to blame; for if he had done his duty properly he would have warned his signalman when he saw him taking off his signals that the line had not been cleared. I do not think that the driver of the Wimbledon train can have been keeping a very good look-out, and he must certainly have been running at too high a rate of speed past the B. box distant-signal, which was at danger when he sighted it over 550 yards distant from the point of collision. If he had reduced the speed of his train, according to rules, he could easily have stopped it when he saw the tail lamps of the Portsmouth train, when still 400 yards distant from him. It should, however, be remarked that this man had been at work for over 15 hours, which is, in my opinion, far too long a time for any man upon whose vigilance depends the safety of the public to be employed. The guards of the two trains seem to have lost no time in blocking the line after the collision. This collision might certainly have been averted if the Wimbledon train had been fitted with a good continuous brake; and it is one of a class which ought to disappear altogether from the record of accidents when the system of interlocking the electrical and the out-of-door signals, now being brought into use upon a few lines, is generally adopted.

Major Marindin has also reported the result of his inquiry into the causes of an accident which occurred on the 16th July last, at Clapham junction station, on the London and South-Western Railway. It appears that the parting of the train in this case was due to the breaking of the pin connecting the coupling link with the draw-bar of the leading carriage in the train. The side chains did not break, but the jerk was sufficient to drag off the bottom of the rear head-stock of the carriage to which the chains were attached. I think it is more probable that the passengers who complained of injury were shaken by this jerk, than by the subsequent slight collision, when the rear portion of the train overtook the carriage and van remaining attached to the engine, for, according to the evidence, the driver was quite aware of what had happened, and took the proper precaution of moving forward and letting the rear portion come gently up to him. It is possible that he may have miscalculated his speed a little, but neither the evidence, nor the result of the collision, would lead to the supposition that the shock was anything but trifling. It is difficult to account for the breaking of the coupling pin, which was not previously cracked or flawed, but it was probably caused by the engine being started too suddenly ahead by the application of steam and the release of the brakes, just when the carriage was upon Plough Lane bridge, with the engine and van upon a descending gradient of 1 in 120, and the rear of train upon an ascending gradient of 1 in 100.

Major Marindin has also reported the result of his inquiry into the causes of an accident which occurred on the 29th July last, near Rugby station, on the London and North-Western Railway. The accident was due to the driver of the up goods train either mistaking the signal which was lowered for the up passenger train for that applying to the goods line upon which he was running, or else paying no attention to the signals a

all. He states that the state of the atmosphere prevented him from seeing the signal-lamps until he was within 30 yards of them, but this is clearly nothing but a lame excuse, for all the evidence, except that of the men with the goods train, is to the effect that these signal-lamps were visible for over 500 or 600 yards; and if this driver's statement were correct it would show him to be still more culpable than he was, for he admits that the distant-signal was at danger, and yet that he ran at a speed of 5 or 6 miles an hour without seeing the home-signal to within 30 yards of it, at which speed it would have been quite impossible for him to have stopped his train of 43 loaded wagons short of the home-signal. This accident to the goods train would probably have had far more serious consequences than the damage of some rolling stock, and the slight injuries to the driver and fireman of the train, if it had not been for the promptitude of the driver of the up auxiliary mail train, which was running alongside the up goods train on the up main line. This man seeing when he passed the van of the goods train that it was running too fast to stop short of the junction-signals, and that therefore it must run off at the safety-points protecting the line upon which he was running, at once took steps to stop his own train, although the signal was off for him, and succeeding in doing so only a second or two before the goods engine ran off at the safety-points, and two of the goods wagons were thrown across the line upon which he was standing, only 5 or 10 yards in front of his engine. The conduct of this driver is well deserving of praise, but at the same time I must remark that it would have been wiser for him to have applied the chain-brake as well as his steam-brake, as this would not only have stopped the train in a shorter distance, but would probably have lessened the shock to those in the train. He probably did not realize that the danger was so imminent as it was, or else he forgot that he had the brake at his command, which is not an unlikely thing to happen with a machine which is only to be used on an emergency. I would observe that the passenger train was made up with two unbraked vehicles behind the rear brake-van, which practice should be avoided if possible, and that the driver had not been made acquainted with the amount of brake power at his command, and upon the train, his evidence showing that he was under a misapprehension on this very essential point.

Major-General Hutchinson has also reported the result of his inquiry into the circumstances connected with the accident which occurred on the 4th March last, at Fenchurch Street Station, on the Great Eastern Railway. This slight accident at the facing-points leading from the left-hand up main line to Nos. 1 and 2 platform lines was probably caused by the left switch of these points not having properly closed when the signalman in the raised cabin nearly opposite to them moved them over preparatory to lowering the signals for the train which met with the accident. The left leading wheel of the engine, which was travelling at a speed stated to be about seven miles an hour, appears to have struck the tip of the left switch, on which it left a slight mark, to have mounted this switch, to have run along the top of it for some distance, and then to have dropped into the space between the left switch and the stock rail; the first mark on any chair was on the third from the heel of the points, after which the permanent way of the line leading to No. 1 platform line was more or less disturbed until the engine stopped about 50 yards from the points, with its leading and driving wheels off the rails, but the bogie trailing wheels and the wheels of all the vehicles composing the train on the rails of the line leading to No. 2 platform and of the main line. There is stated to have been nothing wrong with the leading wheels of the engine, except that the tyres were somewhat worn. These had been turned up before the locomotive superintendent had known that an inquiry would take place; the Company having failed to report the accident until a fortnight after it had occurred. It is probable that a small stone from the loose ballast had inserted itself between the left switch and the rail, preventing the former from closing properly. Had the points been supplied with a locking-bolt as well as bar, the signalman would have been unable to pull over the bolt lever completely; this would have shown him that something was wrong, and the accident would probably have been prevented. In the new signal cabin about to be erected provision will be made for supplying all facing-points with locking bolts as well as bars.

Major-General Hutchinson has also reported the result of his inquiry into the circumstances connected with the collision which occurred on 31st March last, at St. Austell station, on the Cornwall Railway. It is impossible to reconcile the conflicting evidence with reference to the up home-signal given by the driver and fireman on the one hand, and the signalman on the other. The two former declare it to have been off when first seen, about half a mile off, and to have remained so till they passed it; the latter is positive that it was never taken off at all. If the signal was at "danger," then the driver of the train is much to blame for the collision, as he ought to have approached the signal at so cautious a speed as to have stopped at it, instead of (as was the case) over-running it about 400 yards, and then coming into collision with the two trucks on the down line with sufficient remaining speed to knock one over on its side, and to drive the other forward a considerable distance. On the other hand, there is no reason why the points should not have been set and the signal taken off for the train. If the signalman had lowered the signal he must have first made the facing-points right for the up line, and then, to have made the collision possible, have put the signal to "danger," and reversed the points; and though he could have done this while the driver was running the distance of 222 yards which intervenes between the signal and points, there was no apparent motive to have induced him to again open the points for the down line. The signalman was, how-

ever, certainly to blame for not having been in his cabin as the time approached for the train to leave Burngullow, and had the goods clerk not happened to have accidentally been there, there would have been delay in accepting the signal for the train; it is quite possible that when the signalman got to his cabin he was hurried in his work, and after throwing the signal to "danger" as soon as the train had passed it, he might have again set the facing-points right for the down line (their normal position) before the train reached them. Had he not lost his wits after seeing the train coming alone the down line, he still might have prevented the collision by turning the train through a cross-over road leading from the down to the up line, the western points of which are 133 yards east of the loop-points. The driver must have been entering the station at an injudiciously high rate of speed (perhaps forgetting for the moment that his train was not on this occasion, though frequently on others, fitted with continuous brakes); otherwise, with the exceptional means he made use of for stopping, he ought to have been able to pull up short of the trucks, which were not more than 64 yards west of the points at which his engine would have stopped in regular course on the up line. Had modern arrangements been in use at St. Austell station, there would have been an up distant-signal in addition to an up home-signal; this would have permitted the up home-signal being placed closer to the loop-points, and thus have made it almost impossible for the signalman to have shifted these points (supposing that he did shift them) after the home-signal had been put to "danger." It is certainly desirable that the normal position of facing-points at the loops of single lines should be (as a rule) for the arrival line, so that, in the event of a train over-running signals, it should enter the right and not the wrong line. A set of runaway points should be put in at the east end of the down loop line at St. Austell; the absence of these, which allowed the truck to run back to and beyond Par station, might have led to a very serious collision in the present instance. This collision would probably have been avoided had the passenger train been fitted with continuous brakes. The guards, in the present instance, were not able to throw any light upon the indication of the up home-signal at St. Austell. I have observed the same thing in other recent inquiries, and I have reason to believe that their negligence in this respect is to be attributed to the introduction of continuous brakes under the control of the drivers. I trust, however, means will be taken to check this apparent tendency on the part of guards to relax their vigilance in looking out for signals, as this tendency might, in many cases, lead to very serious results.

Major-General Hutchinson has reported the result of his inquiry into the circumstances connected with the collision which occurred on the 9th May last, in the South Stockton goods yard, on the Darlington section on the North-Eastern Railway. Judging from the evidence and from an inspection of the sidings, there appears every reason to conclude that this fatal collision with buffer-stops was mainly caused by the imprudence of the deceased driver in meddling with the points through which his engine had to pass in the course of making up his train. In the darkness of the night it was no easy matter to insure moving the proper points among the number that are congregated at this part of the yard, and it was very unwise in the driver to have attempted to shift any of these points, instead of leaving it to the shunter, whose proper duty it was. By the alteration of points made by the driver it is probable his engine made certain movements not intended or noticed by the shunter, and that this resulted in the facing-points leading to the siding and up main line having been finally opened by the engine passing through them in a trailing direction from the siding; having been thus (contrary to the shunter's expectation) opened for the siding when the engine returned with its load, expecting to proceed on to the up main line, for which the signal was lowered, it ran instead along the siding. Seeing that the shunter had observed the driver meddling with the points, it was, in my opinion, careless in him not to have seen that the points were really right for the departure of the train before allowing it to start. At the entrance of an important goods yard such as South Stockton, it certainly seems most desirable that it should not be possible to lower signals either for entering or leaving the goods yards without some assurance that the points are lying for the directions which the signals indicate.

Major-General Hutchinson has also reported the result of his inquiry into the circumstances connected with the slight collision which occurred on the 24th May last at Exeter (Queen Street) station on the London and South-Western Railway. This slight collision between two empty carriages and the rear portion (consisting of three vehicles) of the 10.20 a.m. up passenger train from Exeter to London, was caused by a misunderstanding between the shunter engaged in forming the train and the driver of the train. Just prior to the collision the 10.20 a.m. up train was in three portions. The rear portion, consisting of two carriages containing passengers, and a brake-van (brought from Torrington by a previous train), was standing on the platform line about 120 yards from the east end of the up platform; the centre portion, consisting of two empty carriages (brought from Devonport by a previous train), had been placed on the up platform line close to the east end of the platform by the Devonport engine after the 10.5 a.m. up train had started; and the front portion consisting of the engine, tender, two carriages, and a brake-van, had been waiting in a dock until the 10.5 a.m. up train had started. As soon as the driver had gone on to the up line he was called back by the shunter towards the two empty carriages in order that he might couple these to the front portion of the train. Owing, however, to the shunter having to stand astride of an ashpit, over which

the empty carriage had been left, he failed to couple up upon the first intention; and then, after getting out from between the vehicles, instead of shouting or going up to the driver so as to inform him that he had missed coupling, he simply waved him back; and this the driver naturally understood to mean that he was to set back with all five vehicles to join the rear of the train. He accordingly set back sharper than he would otherwise have done (causing the shunter again to miss coupling), and did not know that the two portions were not coupled until he felt a tap from the buffers coming together, when he at once stopped his engine; the two carriages had, however, been struck with sufficient force to propel them about 120 yards on a level portion of the line, and then to strike the rear portion of the train at a speed said to have been about four miles an hour. The collision, therefore, is to be mainly attributed to want of caution on the part of the shunter. The carriages which were knocked back on the present occasion might have contained passengers, and on this and on every account it would seem a far wiser proceeding that the same engine should both draw them out of the middle line and then set them back at once on to the rear portion of the train. I am informed that orders have been given for this course to be followed in future.

Colonel Rich has reported the result of his inquiry into the circumstances which attended the collision that occurred on the 16th March last, at Severn Bridge station, on the Severn and Wye and Severn Bridge Railway. From the evidence it appears that the engine-driver of the passenger train received no warning that a coal train had preceded him, when he received the train staff at Lydney Junction. The signalman on duty there was not present when either portion of the coal train passed; but he admits that he knew that a train had gone to Severn Bridge, from the position of the points, and from such trains having been run occasionally in advance of the first passenger train. This man stated that he telegraphed on the block instrument, and received "line clear" from Severn Bridge before he gave the train staff to the passenger train driver, but from the evidence of the station-master and his assistant at Severn Bridge, as well as from his conversation with the engine-driver of the passenger train, this statement is evidently incorrect; further, the time, according to the registries, at which the signalman in D. cabin, Lydney Junction, gave the passenger train to the man in A. cabin was one minute later than the man at A. cabin stated that he telegraphed it forward; and as the clocks in both cabins appear to have agreed, it shows that the man in A. cabin could not have known of the approach of the passenger train at the time that he stated that he telegraphed it forward to Severn Bridge. The collision was caused by the neglect of the Company in not adhering to the Train Staff Rules under which the railway is authorized to be worked, by the neglect of the man on duty at Lydney Junction A. cabin, in not obtaining "line clear" from Severn Bridge before he allowed the passenger train to leave, and by the carelessness of the engine-driver of the passenger train, who ran past the Severn Bridge up distant-signal, which was at "danger," and ran into the van of the coal train, which was standing close to the up home-signal. It is fortunate that the consequences of this dangerous mode of working a single line of railway were not more serious. If the coal train engine had been delayed on its first journey, it might have met the passenger train while running back to Lydney for the second lot of wagons, in which case the consequences would probably have been much more serious. I would strongly recommend the Company to profit by this warning, and not for the future to allow any trains, under any circumstances, to be run in any other manner over the single line of railway, except under the Train Staff and Block Telegraph Regulations, and in accordance with the undertaking to that effect given to the Board of Trade when the opening of this section of railway was sanctioned.

Colonel Rich has also reported the result of his inquiry into the circumstances which attended the accident that occurred on the 30th May last at Chartley station, on the Stafford and Uttoxeter branch of the Great Northern Railway. The accident was caused by the engine-driver of the special train approaching Chartley station at such a speed that his train could not run round the "*S*" curve at the west end of the loop line, and he certainly paid no attention to the orders of the inspector "to run cautiously through the stations." I think that the tendency of the train to leave the rails was increased by the driver applying the powerful vacuum brake to the engine, tender, and leading coach, just before he reached the facing-points. The check which would be given by the brakes to the leading portion of the train, and which would be increased as it reached the flatter part of the incline at the station, would cause the ten following vehicles to close forcibly on the leading portion, and tend to throw the leading vehicles off the rails. The check to the leading portion of the train would be further increased, when the leading brake-van struck the crossing point. The evidence shows, that the train was running at a speed of about thirty miles an hour, which is at all times a dangerous speed to run over the "*S*" curves at the end of the loops, on single lines of railway; but I think it probable, judging by the effects of the accident, that the speed in the present instance was considerably more. The special train was timed to run at a speed of about twenty-seven miles an hour; but as it would probably not ascend the inclines at this speed, it would descend them at a correspondingly increased speed. The Great Northern Railway Company have now issued instructions that the speed through the stations where there are loop lines shall not exceed ten miles an hour, and if this is adhered to, accidents of this kind will certainly not occur. It is desirable that these loop lines should be constructed so that the run through the facing-

points shall always be on the "straight," and that the "*S*" curves shall be at the opposite end, where the trains run out on to the single line through the falling-points. I think it would increase the strength of the permanent way and thus add to the safety of travelling on railways, if the crossings were tied to the check rails and running rails, with strong iron plates which would act as gauge ties.

Colonel Rich has reported the result of his inquiry into the circumstances which attended the double collision that occurred on 22nd July last, at the south-east end of Chester station, on the London and North-Western railway. It appears that the engine-driver of the mail train ran past the down distant-signal of No. 1 cabin, as well as the repeater to this signal, without checking his train. The distant signal is situated about 1,060 yards and the repeating-signal is about 630 yards from the cabin. Both these signals, as well as the home-signal, which is about 155 yards on the Crewe side of the cabin, can be well seen. They were all at danger at the time the mail train approached. Moreover, this train is appointed to stop at the ticket platform, which is about 205 yards long, and is 18 yards on the Crewe side of the home-signal. The light engine that was struck by the mail train was about 138 yards nearer to Chester station than the ticket platform. The engine-driver does not appear to have become aware of his danger, or to have souuded the whistle for the guard's brakes until he was abreast of the engine sheds, which are situated some distance on the Chester side of the repeating signal. He was probably running at a speed of 40 to 50 miles an hour at the time. No dependence can be placed on his evidence or that of his fireman. If steam had been shut off, and the tender-brake alone applied, when these men stated that it was, I do not think the train would have run past the ticket platform. The brakes appear to have been in good order, and, according to the trials that I made with a train exactly similar to the mail train on the day that I made the inquiry, I consider that if the engine-driver had applied the brakes under his control, and whistled for the guard's brakes when he reached the repeater to the distant-signal, his engine would not have run into the light engine, which was standing about 595 yards inside this signal. The driver's statement, that the patent brakes will not act properly when the engine or tender is braked, owing to the buffers between the vehicles of the train having closed up, I found by experiment to be wrong. The only conclusion I can arrive at is, that the engine-driver was asleep, or that he was not thinking about his business, and that the fireman was engaged with his fire, or something else, that prevented his observing the state of the signals and where he was. The collision was caused by the gross neglect of the engine-driver. He has borne an excellent character up to the present time, and I was informed that some time since, when the crank-axle of his engine broke, he showed great activity and presence of mind in preventing a collision and serious consequences, by running forward and stopping a train which was coming in the opposite direction, although he had been severely cut in the knee when thrown from his engine by the bre aking of the crank-axle.

Colonel Yolland has reported the result of his inquiry into the circumstances which attended the collision that occurred on the 13th June last, between a special passenger train and some coal trucks, at the Staines station of the London and South-Western Railway. From the statements it appears that a shunting engine from Kingston, with two vans, reached Staines station about 11.27 a.m. on the day in question ; and it ran forward and passed on to the down line leading to Reading, and at once commenced shunting and marshalling goods trucks in the sidings and on the down line, under the protection of the starting-signal at the west end of the down platform. An up train was due from Reading about 11.20 a.m., and, in consequence, the junction points worked from the west signal-box were set right for the down line to Reading. A special passenger train from Waterloo Road station was appointed to leave the station at 10.40 a.m. for Windsor, it being one of the Windsor race days; and the train left at 10.46 a.m. It consisted, at that time, of an engine and tender, one horse-box next the tender, one brake-van, 16 carriages, and one brake-van, and it took on three more horse-boxes at the rear of the train at Clapham junction, making up a total of 22 vehicles independent of the engine and tender. The train was provided with a hand-brake on the tender, and another on the leading brake-van, and the guard in the last van had a brake in his van, which was connected with another brake (Newall's) in the carriage in front of the van. This train stopped at Vauxhall, Clapham junction, Richmond and Twickenham, and was travelling all right when the driver approached Staines station, at a rate of 35 or 40 miles an hour, when he states that he shut off the steam before he reached the Staines down distant-signal, which, as well as the down home-signal, were both off for him to run into Staines station ; but when he had passed under the over-bridge a short distance (117 yards) east of the eastern signal-box he found the down starting-signals at the junction at the west end of the platforms were on at "danger" against him. He says he was running at that time at from 16 to 18 miles an hour, and he sounded the small whistle first, and afterwards the brake-whistle, as he was passing the eastern signal-box, and also reversed his engine and applied the steam the reverse way, and his fire-man put on the tender-brake, and kept it on until the collision occurred, when he thinks he was running about five or six miles per hour. The leading wheels of the engine were thrown off the rails, and the engine had the buffer plank broken, smoke-box

knocked in, and the connecting-rod bent. The tender was slightly damaged. No other vehicle in the passenger train was thrown off the rails, and the leading van only was damaged. The fireman also states that the whistles were sounded. The head guard, riding in the front van, heard the sharp whistles only, but no brake whistles, and no other person appears to have heard any whistles. The assistant-guard, riding in the van near the rear of the train, was not aware that anything was wrong until his van got to the east end of the platform, when he saw that the starting-signals were at "danger," and he then applied his brakes. The collision took place about 600 yards west of the over-bridge where the starting-signals first became visible to the driver of the down train. The line rises slightly on a gradient of 1 in 511 from this over-bridge to the junction, and from it rises on gradients of 1 in 102 for a very short distance, and then on 1 in 165 to beyond the point where the collision happened. Several causes combined to cause this collision. The train was not supplied with a proper amount of brake power, as brakes on three vehicles out of a total number of 22, independent of the brake on the tender, are entirely insufficient for the control of such a heavy train; and, in addition, the guard in the last van did not hear the whistle for the brakes, if it had been given, and was not likely to do so in such a long train. Next, I do not think it is by any means clear that the driver was keeping a sharp look-out ahead, or that he applied the brake or sounded the whistles as soon as he stated; but it must be admitted that the signalling arrangements are not well adapted for the running of special and ordinary trains, some of which stop at Staines station, and others run through without stopping, when the signalmen do not know until the train is actually entering the station yard, in all cases, whether the train will stop or not, and the engine-driver of a non-stopping train, after receiving "all right" signals on the down distant and down home or stop signals, worked from the east signal-box, does not know until he has passed under the over-bridge at the east end of the station whether he will find the down starting-signals worked from the west signal-box standing against him or not. This defect in the signalling arrangements would be corrected by doing away with the slots altogether, and by substituting down distant-signals worked from the west signal-box and placed under the down home or stop signal, at the east end of the station, to let the driver know whether the station signal for the line he was about to run forward on was on or off, so that he must stop or might proceed, at the same time that the down home or stop-signal told him whether he might enter Staines station.

Colonel Yolland has inquired into the circumstances connected with the fatal accident that occurred on the South Eastern Railway to G. Coleman, a goods guard, while riding in a brake-van of the 10 p.m. up Folkestone goods train, from a sheet-pole belonging to a truck in the 8 p.m. down goods train from London to Ashford having become detached from that truck, and been forced into the leading end of the brake-van, in which the man was riding, and thence through the roof of that van, striking and killing the man as it passed through it, on the early morning of the 14th June. From the statements, and from an examination of the broken fragments of the sheet-pole and damaged brake-van, No. 6187, it appears that a portion of the company's trucks have wooden sheet-poles fixed in iron sockets at the circular tops of the wooden ends of the trucks, in which goods are stowed for the purpose of being conveyed by railway from one district of country to another, or from town to town; and these sheet-poles are used for supporting the tarpaulin sheets, which are placed over the goods in order to keep them dry. When fixed in these sockets, there does not appear to be any objection to their use. But at other times, when it is desired to load the trucks more fully, these sheet-poles are taken out of these sockets, and they are suspended outside the sides of the trucks by iron chains from each end of the sheet-pole. On the night on which the accident happened, a sheet-pole rather more than 16 feet in length was suspended at the right side of truck No. 6,867, placed fifth or sixth from the front end of the 8.0 p.m. down goods train to Ashford, which consisted of about 25 trucks when it left Paddock Wood station for Ashford at 1.0 a.m on the 14th June. When this train reached Ashford the sheet-pole was missing, but the chains by which it had been suspended from the circular tops of the ends of the truck were there, hanging down, and the sheet-pole had either broken or been torn away from the chains. Again, the 10 p.m. up goods train from Folkstone to London left Folkestone about 11.30 p.m. It then consisted of an engine, 45 trucks, and two goods guards' brake-vans, with two guards; one riding in the van, No. 6,187, next the engine, and the other in the brake-van at the rear of the train. This train stopped first at Ashford, where two trucks were dropped, and 15 trucks and another engine were taken on, and guard Coleman, who was riding in the leading brake-van, was seen, and he was then all right. This train was stopped by signals for about two minutes at Paddock Wood station. Guard Coleman was not seen, and the train did not stop afterwards until it reached Tunbridge. Nothing was known to have happened to this train while running between Paddock Wood and Tunbridge, but the engine-driver after the train had stopped at Tunbridge, observed that guard Coleman did not get out of the leading brake-van to attend to his duties, and the driver got down off his engine and went to the leading brake-van, and observed that there was a hole broken in the leading end of the van; he then got a lamp, entered the van, and found the man lying on his back dead, he having been killed by being struck by the sheet-pole as it passed from the end to and through the roof of the van. Marks on the ballast, apparently made by the end of a pole, were found by one of the platelayers over a length of about

a quarter of a mile, half a mile on the London side of Staplehurst station; and two portions of eheet-pole itself were found by another platelayer three-quarters of a mile south of Staplehurst signal-box, and one piece of the iron fastening (the long arm with two iron bolts through it) was found near the same spot on the outside of the down line. It appears therefore to be highly probable that the fastening between the sheet-pole and the truck first broke at the trailing end as the down goods train was running, and that this trailing end, hanging from the truck, made marks in the ballast before Staplehurst station was reached, but that the leading end of the sheet-pole was not broken from the truck until nearly three-quarters of a mile from Staplehurst had been reached, and that when this leading end separated from the truck it passed at once across to the up line, forced its way through the end of the goods guard's brake-van, No. 6,187, and killed guard Coleman. I understand that this is the first accident of the kind which has happened, but the chains by which these sheet-poles are suspended at the sides of the trucks have occasionally been found broken. This breaking away of the sheet-pole might have happened as the goods train was passing a passenger train with serious consequences to the passengers in the train. Under these circumstances I recommend for the consideration of the directors of the ratlway company that these sheet-poles should be slightly shortened, so that their ends might be supported by iron sockets placed inside the circular tops of the trucks, and that the chains also should be shortened, so as not to be long enough for the sheet-poles to hang outside the sides of the trucks. In this way, if a sheet-pole got out of the socket by which one end was supported, or if a chain should break, the sheet-pole would merely drop into the inside of the truck, and not be liable to get outside of it. On many lines of railway these sheet-poles are not used.

Colonel Yolland has reported the result of his inquiry into the circumstances which attended the accident that occurred on the 26th June last, to the 6.30 p.m. up passenger express train from York to London, on the Great Northern Railway, at Werrington junction, which is about 3½ miles north of Peterborough station. From the statements, and from inquiries on the ground, it appears that on the day in question the 6.30 p.m. up passenger express train from York to London, when it left Grantham station four minutes late, consisted of an engine and tender, one brake-van, five passenger carriages, and two brake-vans at the tail of the train, with two guards, one riding in the front and the other in the rear brake-van; that it was fitted throughout with the vacuum-brake; and as it approached the Werrington junction, and was travelling at the rate of about 45 miles an hour, the driver felt a sudden jerk, and the engine was lifted up on the right side, caused by the right-hand connecting-rod of the engine breaking. The engine was a six-wheeled engine with four wheels coupled, the driving and trailing wheels being 6 feet 6 inches in diameter, and the leading wheels 4 feet in diameter, there being 8 feet 3 inches wheel base between the driving and trailing wheels. The driver states that, when he felt the engine lifted up, he shut off the steam at once, and opened a valve so as to apply the brakes throughout the length of the train; that he thinks the engine broke away from the tender just after passing the facing-points that lead to the up goods line. The head guard, riding in the van next the tender, on feeling the sudden jerk, began to put on the hand-brake as quickly as possible; and he thinks his van got off the road before reaching the junction. The tender stopped about 470 yards south of the first indication that could be found on the ground of anything being wrong with the train, and the engine, after the screw coupling between it and the tender had broken, ran between 1,100 and 1,200 yards south of the spot where the tender stopped on the rails of the up main line, about 220 yards south of the centre of the signal-box. This signal-box is about an equal distance south of the first indication that any part of the train was off the rails. The first mark on the permanent way was found on the ballast, outside but close to the right rail of the up line, and 36½ yards south of this first mark, a part of the connecting-rod of the vacuum-brake on the engine was found buried in the ballast, with heavy wheel marks indented on it. This broken rod evidently caused some wheel to get off the rails. Four and a half yards beyond this broken rod the first indication of a wheel being off the rails was seen inside the left rail, and from thence southwards, mostly on the sleepers at the end of each rail length, distinct marks of one or two wheels being off the rails could be seen on the sleepers inside the left rail of the up main line and outside the right rail. Some chairs and check-rails were also broken on this line, and an occasional mark of a third wheel being also off the rails could be seen before the junction was reached, as recorded on the drawing received from the district engineer, Mr. Ogilvie, of the Great Northern Railway; and after the signal-box at the junction had been passed marks of wheels off the line were found on the cross-over road of the down goods or slow line to the down main line, and these were continued for more than 100 yards, with other marks, also on the up main line, and the timbers and sleepers were much damaged. The tender was found on the rails of the up main line. The whole of the vehicles remained coupled to each other, and to the tender in front. All were off the rails, except the last brake-van, which was on the down goods or slow line, and the leading axle of this van is said to have been badly bent. The carriage behind the leading van had turned over on to its left side, and the carriage in front of the two brakes at the tail of the train had turned over on to its right side. The remaining vehicles were all upright, although off the rails. When the engine was examined it was found that

the connecting-rod, 8 feet 3 inches in length, on the right side of the engine, for coupling the driving and trailing wheels together, had broken 3 feet 7½ inches from the leading end attached to the driving-wheel, and the longer piece attached to the trailing-wheel is that which must have broken a hole in the side foot-plate of the engine between the driving and trailing-wheels, and which also broke off the piece of the adjusting-rod of the engine brake gear, between the trailing-wheels and brake shaft, which was found on the line. The dimensions of the connecting-rod where the fracture took place was 4 inches by 1½ inches. The dimensions of the adjusting-rod where it was broken was found to be 2 inches by ⅞ inch. The screw-coupling that broke between the engine and tender was 2½ inches in diameter. In the fracture of the connecting-rod there is an appearance of an unsound place in it, which, however, did not seem to have extended to the outer surface. The engine was delivered to the Company in 1868 by the makers, the Yorkshire Engine Company, of Sheffield. It was under general repairs in Doncaster plant in October, 1880, and under slight repair in Doncaster running sheds on April 20th, 1882. The accident was evidently caused by the fracture of the connecting-rod of the engine; and the revolution of the longer portion attached to the trailing-wheel of the engine evidently caused it to break in two places the adjusting-rod of the engine-brake gear, between the trailing-wheels and brake-shaft on the right side of the engine, and the broken-off piece of this rod, which is about 5 feet 3 inches in length, must have fallen on the rails, and thus caused some wheel to mount and get off the rails. The revolution of the long piece of the connecting-rod also caused it to damage the side foot-plate and the end of the trailing buffer-beam of the engine, right-hand side, and to bend it backward, and the right-hand corner of the leading buffer-beam of the tender. I was not enabled to obtain any distinct evidence whether the opening of the valve of the vacuum-brake by the engine-driver had the effect of putting on any of the brakes in the train or not; but from the comparatively short distance which the tender and train ran before they stopped, I think that some brakes must have been applied to the wheels of the vehicles. It will be noticed that the vacuum-brake gear was more or less damaged on the vehicles throughout the length of the train, except on the engine and in the last break-van. From the small amount of the damage that was done to the two carriages which were thrown over on their sides, I do not think that they were dragged on the ground any distance after they had fallen over on their sides, and I think it fortunate that the screw-coupling broke when it did, or the results might have been far more serious.

NOTES.

In the Geological Section of the British Association, presided over by Mr. R. Etheridge, F.R.S., Professor Boyd Dawkins spoke on the proposed Channel Tunnel. He said the duty of examining the physical structure of the cliffs on either side of the straits of Dover, and of collecting all the data necessary for the purpose of a Channel tunnel, having fallen to his lot, he thought it not inopportune to lay the results of his inquiry before that meeting. The general conclusions at which he arrived were that the lower beds of grey chalk and chalk marl were the only strata in the chalk sufficiently impervious to allow of the construction of a tunnel in the dry. Secondly, that the outcrop of chalk marl and the grey chalk between Folkstone and the Shakespere Cliff was the best position for a tunnel which could strike the lower part of the grey chalk and remain in it throughout, so as to join the workings of the French Channel Tunnel. Third, that the faults in the lower part of the grey chalk do not allow of free percolation of water, and are not likely to become a serious obstacle to the work. Fourth, that the strata above the grey chalk are porous and traversed by open fissures, and they allow of free access of water, both sub-ærial and marine, and therefore offer great difficulties in the way of the construction of a submarine tunnel, which are not presented by the lower parts of the grey chalk. The rocks on the French side were much more shattered than those on this side; but the French engineers found no great difficulty in carrying on their works, and they were boring towards England at a rapid rate. There was nothing original in his conclusions; he was simply verifying the conclusions of all those who had gone before him, viz., Mr. Phillips, in 1820, and Mr. Price. All the reports of the Commissioners which inquired into this subject agreed that the lower part of the grey chalk and marl No. 2 were the strata best fitted to tunnel through. Mr. de Rance, who in 1876 was associated with Mr. H. Price in a geological survey at Folkestone, arrived at conclusions entirely consonant with his (Professor Dawkins's).—Mr. W. Topley, in his account of the synclinal structure of the Straits of Dover, said the researches of the French geologists had confirmed the inference of the British geologists that the Straits of Dover were not a fracture, but a depressed valley, corresponding to the valleys around the Weald. This should be taken into account when determining the course that the Channel Tunnel should take. In the dis-

cussion which followed, Sir J. Hawkshaw said, after all, the line which the Channel Tunnel should take would have to be decided by engineers. What they had heard that day was very much like a tale that had been told, for the question had been before some of them for the last fifteen or sixteen years in one shape or another. In his opinion the precise line of sea tunnel had not yet been fixed. Though it might be very proper for some of them to say the Tunnel would best be made in such and such a line, still the matter could not be so decided, inasmuch as one-half of the Tunnel would be made by the French, and one-half by ourselves; and it was clear that in any final settlement the French must be taken into consultation. That had not yet been done. The borings that had been made on either side were mere drift ways. In February he saw the gentleman in charge of the French works, who told him that no conclusion had yet been come to as to the precise line that the Tunnel should take. We could not now speak of the line as definitely settled; that would have to be done hereafter. Water absorbed by the chalk was of no consequence to engineers, who would only take into account water flowing through free fissures. Professor Prestwich considered the probabilities of meeting with open fissures and faults in the chalk. He thought it possible that open fissures would be met with, and they would be pretty certain to meet with faults which would impede engineering operations. If a tunnel were made, it could be done better in the chalk than in any other stratum.—Sir F. Bramwell said he had examined the borings on this side of the Channel, which were made in a stratification which was practically water-tight, and geologists agreed that this stratification extended all across the Channel. In reply to the question whether engineers could follow the undulations of the bed, he thought they could, but that it was not necessary to follow them, as engineers could make reasonable deviation. He did not think it probable that large open fissures would be met with, for if they originally existed they must have become silted up. As an engineer, he asserted that he could cross a fissure 30 or 40 feet wide, 200 feet under the bed of the sea, without much difficulty. Mr. Whittaker agreed with Sir John Hawkshaw, that the question was one for engineers rather than geologists.

Proposed Electric Railway for Philadelphia.—A committee of the Philadelphia Park Commissioners met June 27th, and received the following communication from Superintendent Thayer upon the practicability and advisability of constructing and operating an electric railway in in West Fairmount Park:—"In order to assure myself of the practicability of the proposition which has been presented for your consideration, I visited Mr. Edison's works, at Menlo Park, and carefully inspected the electric road which he has in operation at that place, and which is 3½ miles in length. As a description of this remarkable adaptation of recent discoveries in electricity to a useful purpose may be of some interest in this connection, and as I was directed to report upon the practicability of the matter, I will endeavour to explain it briefly. The motive plant consists of a steam-engine, of 100 horse-power, and five dynamo-electric machines, capable of generating currents of great quantity, but very low intensity. The machines are placed in a building at Menlo Park, and are connected with the rails of an ordinary railway, situated at about half a mile from the works, by an insulated copper cable laid underground. The power developed by the stationary steam engine puts in motion the armatures of the dynamos above referred to, and the rapid revolution of the armatures in the "fields" of the large electro magnets develops the currents, which, being taken from the "commutator" by brushes suitably arranged, are transmitted from thence by the cable to the rails of the track. By this means the energy originally developed by the combustion of the coal under the boilers of the steam engines is transmitted to a distance and placed in the rails of the track. It now simply remains to reconvert this energy into useful work, and to cause the cars to move. This is accomplished in the most simple manner by a reversal of a portion of the operation as follows:—A dynamo-electric machine is placed under the car, and is connected electrically with the wheels. The current passes from the rails of the track to the wheels of the car, and thence to the dynamo. The armature of the latter is thus at once put in rapid motion, and by a simple and efficient mechanical arrangement the motion thus developed is transmitted to the wheels, which serves as drivers, and the car is propelled along the track at any rate of speed that may be desired, depending simply upon the horse-power of the dynamo engines used. The practicability of the matter, as far as the power proposed to be used is concerned, is thus seen to be assured. I will next consider the practicability of the last route described and numbered in the plan. I have carefully gone over the route on the ground, and examined it at all points. My professional opinion, as an engineer, is that it is practicable throughout."

Upon several very fine new passenger cars which the Fitchburgh Railroad is building a novel invention is to be introduced. On one side of the car is the lavatory, consisting of a marble slab with a set bowl, and beneath it is a cylindrical tank containing water under 40 pounds pressure, obtained from the air-brake system, and connected by pipes and faucets with the lavatory. Also connected with it are 50 feet of hose, which can instantly be utilized for extinguishing a fire in the car or elsewhere near by. The tank is filled either rom a hydrant or by buckets from the outside of the car, and where the air-brake system is not used by a railroad, an air-pump can supply the requisite pressure.

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MILITARY RAILWAY OFFICIALS.

EVERY new decade adds some fresh problem to the study of war,—something which takes its place as a consideration to be allowed for, a danger to be grappled with, or a means to be used,—and generally all three. Thus, torpedoes are developing into terrible perfection, and the next great naval war will show us what their work will be, and whether they will revolutionize all modes of fighting at sea. The ten years that included the Franco-German and Russo-Turkish wars made railways an essential element in a campaign, just as those which preceded them had introduced the great increase in rapidity of firing, which will culminate when repeating rifles are adopted as the weapon of the infantry. New words in war are printed in very large letters of red and black; but our Horse Guards and Admiralty are slow at their lessons, and take a long time to spell them out. The denunciation of bureaucracy and red tape sometimes threatens to become a formula, though no doubt much daylight has been admitted of late into regions formerly lit only by official candles; but still it would be gross flattery to say that in all respects our army keeps up to the times.

In this particular matter of railways, for instance. That they are necessary is obvious, and about them here is plenty of experience to be had gratis, of other people's buying, so how is it that now we are not able to turn out a piece of work perfectly done? We have some railway engineers, indeed, among the sappers, properly trained in laying down and taking up rails, repairing and destroying track, and so on; and when a war is impending, we give them a few hurried lessons in the management of railways and then send them to Egypt to make communications for our troops. They do their own business well, mend and make their lines as required; but when the lines are made, there are endless delays and difficulties about using them, just when they are most urgently required to be in full working order. It is an anomalous state of affairs, but inevitable with our present arrangements. It is easy to take the men out for exercise, and make them lay down little railways and pick them up again, or even run little trains along little journeys; but such manœuvres teach them exactly as much about working a real line with an immense pressure upon it, as a child's doll tea-party teaches her of housekeeping. How can they rehearse such work at Chatham or Woolwich? Where are the crowding trains, getting in each other's way, the piles of stores growing ever larger, while impatient telegrams demand them every hour, the troops that must be sent to the front, the sick and wounded that must be brought to the rear? How far can a fortnight's training under the London, Chatham, and Dover Company fit them for all this! When it comes to the point, the corps must fall back upon whatever stock of mother-wit, *savoir faire*, and organizing power it may prove to contain.

There is hardly another nation in Europe that is not better prepared for such work than England, the mother of railways. In France, the men of the Railway Engineer Corps put in only 12 months with the colours, and then are drafted for the rest of their military term into the service of one of the railways, from which they can always be summoned when needed. In time of war the special work of these soldiers is the construction of the new lines required; while for their working, a civil division has been formed in connection with each of the military companies, consisting of men in the ordinary service of the civil railways, who can be called up to undertake the general service, maintenance, and traffic. Altogether, the Minister of War can command the services of 12,000 qualified railway mechanics and officials. What have we to compare with this? In Italy, the men of the Military Railway Corps are taught signalling and the use of station apparatus, as well as the ordinary work of construction, repair, and demolition; and the Alta Italia Railway Company trains a number of them as engine-drivers and stokers, putting them through an examination for a certificate of competency. The Austrian system resembles the French, and the Minister of War can at once draw upon the railway companies—not only for mechanics, but also for telegraph operators, and for telegraph, traffic, and constructive engineers. In organizing the German Railway Regiment, the difficulty of training the men to actual work under practical conditions was overcome by the patriotism of the railway companies, who came forward voluntarily to co-operate with the Government in securing the success of the new arrangement.

Why should it be impossible to organize something similar in England? Why should the men of any Railway Engineer Corps know only how to make and un-make property railways, know nothing at all of how to work them when they are

made? Can no public spirit be expected from our railway companies? If a German company will risk some inconvenience and loss in order to be of service to the country, is it quite out of the question that an English one should do the same? Suppose that each company were to agree to employ a certain number of Army Reserve men in its various departments, such men could be enrolled as a Special Railway Reserve, and when called up, would constitute a complete staff, ready to hand for the working of military lines, supplementing the embodied Railway Corps, which would be employed only on works of construction, maintenance, repair, and demolition. The fact that such a number of situations were open to Reserve men only, would add to the attractions of the army, and there would always be enough applicants to enable the companies to exercise their powers of choice and dismissal. It would not be necessary that they should employ so many Reserve men as to leave themselves in serious perplexity when they were called up; and if the French companies can meet this difficulty, it cannot be insuperable, certainly it ought to be overcome, for the sake of the public interest.

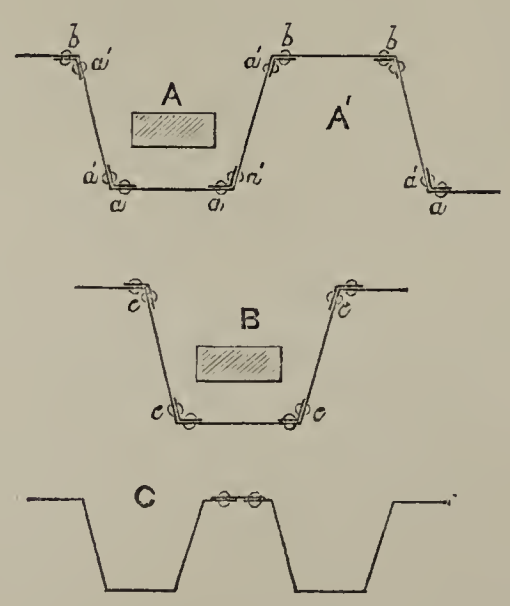
LONG SPAN BRIDGES AND VIADUCTS, IN IRON, STONE, BRICK, AND TIMBER.

(*Continued from page* 231.)

IT is not always necessary to have so great a width as that taken above for a three girder bridge, for if the span is sufficiently small to allow of the centre girder not rising more than two feet six inches above the rail level, the six foot between the two lines of railway will suffice without any additional clearance being provided. Whether this can be done will depend upon the span and headway, but it will not often occur that this construction can be used for long span bridges, as where the headway would be sufficient to allow the major part of the girder to to depend below the floor it will generally admit of the entire girder being placed under the rail.

For some years past a kind of flooring shown in longitudinal section at *A* Fig. 12 has been in use on some of our railways, but a little careful examination will show that as constructed it is very faulty.

FIG. 12



The form has been designed, it should be observed, for places where the headway is extremely limited, the sleepers being laid in the troughs at such a level as to allow the rails to clear the tops of the troughs by two or three inches. The distance apart of the troughs will depend on the spacing of the sleepers. If this flooring is made one foot deep which will do for widths of 12ft. 6 in. the total height from the underside of the flooring to the top of the rail will be about 1 ft. 8 in.

On lines of railway in the hilly districts of this country this want of reasonable headway is a great trouble to those who have to design the requisite structures for carrying the railway, over public roads, and more especially even over rivers and canals, and a good deal of this might be avoided, if when the levels of the line are being settled by the engineers they would give a little attention to the characters of the bridges to be used and not determine levels merely in reference to points of the centres of the railway and road respectively. If for instance we decide that two feet is sufficient from rail level to underside of flooring, that height must be allowed over the point where the road is highest and with a rising road under a very oblique bridge this at one corner will be greatly different from that in the centre of both road and railway, and by deciding this matter in the outset much subsequent loss of time, and trouble and perplexity, may be avoided.

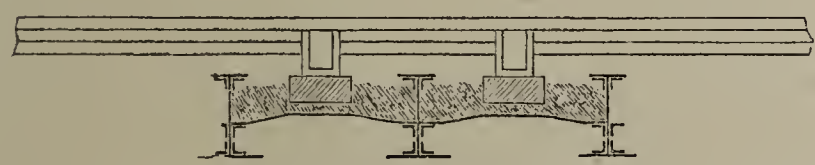
This flooring consists virtually of a series of girders of which the flanges run from the web of one to that of the next girder. The sleeper resting on ballast its weight is taken on the bottom plate, which itself is taken on the heads of the rivets *a a*, thence the load passes to the side plates putting shearing strain on the rivets *a' a'*., these again pass the load through the upper angle irons, and again it becomes dependent upon the rivet heads at *b*. It is always bad to rely upon the rivet heads, and it should never be done where it may be avoided. By arranging the plates and angle irons, however, as shown at *B*, it will be observed that the load affects only the rivets *c c c c* which are put in shearing strain, the remaining rivets being required only to keep the plates up to the angle irons.

But the best plan perhaps is to use (where this form is indispensable) the rolled troughs *C*, then the question of rivets is altogether obviated, as to how these troughs will stand the vibration of railway traffic, whether they will go at the roots or not, they have not been sufficiently long in use for us to say.

But taking all these constructions we are *not* favourably inclined towards them, they are not convenient to get at to rivet, and cannot be finished in a hydraulic rivetter, and as all the rivets belong to strictly constructional, not merely covering elements, this is a very important point. The difficulty with the troughs *C* is to get them rolled of a sufficient depth to give the required rigidity.

In Fig. 13 is shown a longitudinal section of a class of flooring we have used largely in preference to those shown above, and several advantages can be claimed for it. Light cross girders as shown are used, carrying buckled plates between them, on which is placed the ballast necessary for bedding the sleepers. We will compare this with the previously described system. At *A* Fig. 12 the bottom plate carried by the rivets *a a*, corresponds to the bottom flange of *one* of the girders shown at Fig. 13.

FIG. 13



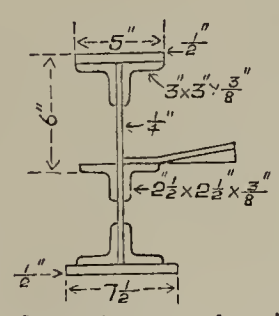
Now it is evident that when a pair of wheels comes over the sleeper at *A* we shall have the full load of that pair on the *one* flange plate, but in Fig. 13 there can only be *half* the weight of a pair of wheels on any one girder at a time, for if the wheels be over the sleeper, the buckled plates distribute the load between two girders, and if the wheels are over the centre of the girder the rails distribute the load on two buckled plates which again distributing it, a quarter in each direction, results in producing a maximum load of *half* one pair of wheels on a girder.

It is advisable when a system of this class is to be largely used, to determine on a type of girder that may be employed throughout the line; the girders must be spaced to suit the distance of the sleepers, say 1 ft. 8 in. Take first a single line of railway, 15 ft. wide between the main girders. The ballast being 6 in. thick will weigh 60lbs. per superficial foot, the floor plates 12lbs ($\frac{1}{4}$ in. buckled plates including strips and rivet heads). The dead load from these sources will be for the surface carried; 15 ft. × 2 ft. 8 in. × 72lbs. = 2,880lbs. = 1·285 tons. We will call the greatest load on a pair of driving wheels 16 tons, then half of this or 4 tons upon each rail will be the maximum live road upon the girder. The weight of the girder itself will be about 0·52 ton, total dead load uniformly distributed 1·805 tons. It will here be observable that our construction (Fig. 13) enables us to use no more ballast than is actually necessary to steady the sleepers, as we can carry the buckled plates at any level that may be appropriate, whereas in the arrangement shown in Fig. 12, sufficient ballast must be used to raise the sleeper the required height from the bottom of the trough; thus to give a 2-in. clearance between the rail bottom and the top of the trough the thickness of ballast requisite will be 13 in., but this does not cover the whole surface as the ballast does in the case shown Fig. 13, so that the average thickness after deducting the space *A'* will be 8 or 9 in., and this ballast *must* be kept well up to prevent the rails from being pressed down on the tops of the troughs, where as with the form we adopt they can never come upon the girder tops, the sleepers being sustained by the buckled plates at the proper height. The strain on either flange of the girder will be (by the ordinary formulæ), if the mean depth is one foot *W*, the dead load and *w* the live load of 4 tons.

$$S=\frac{Wl}{8d}+\frac{w\times 5}{d}=\frac{1{\cdot}805\times 15}{8\times 1}+\frac{4\times 5}{1}=23{\cdot}384 \text{ tons.}$$

Adopting the Board of Trade allowance of working strain, 5 tons per sectional square inch, we require the areas of the flanges to be 4.676 sq. inches, gross in the top and nett in the bottom flange. In order that the 5 tons may not be exceeded all that is taken as efficient flange must be *outside* the one foot of depth, hence the vertical limbs of the angle irons must not be considered in determining the strength of the section. Let the angle irons be 3 in. × 3 in. × $\frac{3}{8}$-in. thick, then, their two horizontal limbs will together give an area of 2.25 sq. in. which deducted from the 4·676 sq. in., leaves 2.246 sq. in. This will be made up by a plate 5 in. by $\frac{1}{2}$-in. thick. The web may be $\frac{1}{4}$ in. thick. Keeping the same sized angle irons for the bottom flange and using $\frac{3}{4}$ in. rivets, the area (nett) of the horizontal limbs will be 1.687 sq. in., leaving required a (nett) area of 2.989 sq. in., or 6 in. × $\frac{1}{2}$ in. thick, to which must be added $1\frac{1}{2}$ in. for loss by rivet holes, making the width of the bottom flange $7\frac{1}{2}$ inches. The angle irons supporting the buckled plates may be made $2\frac{1}{2}$ in. × $2\frac{1}{2}$ in × $\frac{3}{8}$ in.

FIG. 14



Let us see how the weight of this girder comes out. The total depth is $13\frac{3}{4}$ in.

There is a gross running area of 22.187 sq. in. which gives with 5 per cent. added for rivet heads, 1164·80 lbs=0·52 ton for the weight of the girder, and as we assumed it as 0.52 ton our calculations are accurate as they stand.

This co-incidence of weight is remarkable, but it is a proof of the accuracy of the table (given in an earlier number) by means of which the assumed weight is determined from the useful load. In this the useful load was found to be, in strain-producing capability, equal to 12 tons equally distributed, the table gives, for ratio of depth to

span 15, 0.00289 and, $0.00289 \times 12 \times 15 = 0.520$ ton. The equivalent in distributed load to the symmetrical load actually accruing is determined by equating the moments of strain thus; let W = required equally distributed load, l = span, w = one of the symmetrical loads and y = its distances from the nearest point of support; then

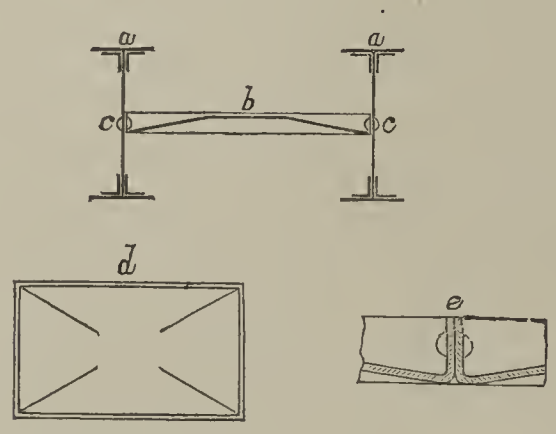
$$\frac{W.l}{8} = w.y. \quad \therefore \quad W = \frac{8.w.y}{l} = \frac{8 \times 4 \times 5}{15} = 10{\cdot}667 \text{ tons.}$$

Then adding the weight of ballast and floor plates we get $10{\cdot}667 + 1{\cdot}285 = 11{\cdot}955$, or practically 12 tons for this purpose.

There is a difficulty here, as in all close work, about the rivetting, and especially as a great deal of it has to be done in erection, and on this account bolts have frequently been used instead of rivets, but the work thus finished is not nearly so satisfactory as rivetted work, as it cannot be made watertight in the ordinary way.

A method of forming the floor plates has occurred to us by which the difficulty as to the rivets may be avoided and at the same time some of the rivetting saved; this construction is shown at Fig. 15.

FIG. 15



a, a are the cross-girders shown with the floor plate *b* between them in section. It will be seen that this floor plate is buckled, but instead of being heft with a horizontal fillet as usual the edges are flanged up, so that they can be rivetted at once to the web of the girder without the intervention of a connecting angle iron, which with its row of rivetting is thus saved, *d* is a plan of the plate.

These flanges can be made at the same time the plate is buckled, all being done at one operation under a press. The joint strips of the floor plates will also be saved by this method, and the joints made with one instead of two rows of rivets, and the vertical flanges will impart additional stiffness to the flooring, the joints being as shown at *e*.

The flanges may be turned either up or down, but for the purpose of rivetting on the site it is more convenient to have them turned up, so as to avoid having to rivet overhead.

These plates may ultimately be filled up level with the edges with asphalte concrete of a quality that will stand the vibration, so as to afford a flush surface from which the wet may drain off to either end of the bridge.

There has been an almost innumerable quantity of different designs for bridge floors from time to time brought forward, but, taken altogether, we think that the use of the buckled plate in some form or other is decidedly superior to every other system generally known, and in our own practice invariably adopt it where it is possible so to do.

There are several disadvantages in using three girders for long span bridges when the trains have to run between them. First, there is the widening of the railway in order to get the necessary clearance; and, again, in putting up three girders there must be more work than in the erection of two. There is twice the amount of fitting in the cross girders, and there will sometimes be an actual increase of weight in the main girders when three are used, as the adventitious elements, stiffeners, &c., will be increased.

We will now see, under similar circumstances, with freedom as to proportions, what will be the difference of weight in the cross girders between those used for two and for three main girders for a double line of railway. The least clearance we can have is for the two girder arrangement 25 feet clear width for the two tracks, and for the three girder arrangement 14 feet clear for each track; let the main girders be 2 ft. 6 in. in width.

Assume the live load as 8 tons on each driving wheel, and let the cross-girders be taken as running from web to web of the main girders. In the first or two girder system the cross girders will be $25 + 2{\cdot}5 = 27$ ft. 6 in. in length. As we are not limited in dimensions, we will make the cross-girders of the most economical proportions and of uniform section throughout in both cases.

In a previous article (January 1881, page 20) we have determined a formula giving the most economical depth for plate girders of a form analogous to those of which we are now treating; it is

$$d = \sqrt{\frac{w.l^2}{48.f.t.}}$$

In which d = depth in feet, l = span in feet, t = thickness of web in inches, including all stiffeners, packings, &c., and f = working strain of iron in tons per square inch.

The maximum moment of strain for the running load will be, $M = 8 \times 10{\cdot}75 + 8 \times 5{\cdot}75 = 132$ ft. tons, hence the uniformly distributed load giving an equal maximum moment will be,

$$W = \frac{8 \times M}{l} = \frac{8 \times 132}{27{\cdot}5} = 38{\cdot}4 \text{ tons.}$$

If the girders are 4 feet apart centre to centre the weight of plates and ballast at 72 lbs. per superficial ft. will be for each girder, $27{\cdot}5 \times 4 \times 72 = 7920$ lbs $= 3.54$ tons, which added to the above gives 41.94, the weight of a girder to carry this "useful" load will be about 2·63 tons, making a total load of 44·57 tons distributed, and this will be the value of $w.l$ in the formula for most economical depth.

Let the webs be $\frac{1}{4}$ inch thick strengthened every four feet by 6 in. $\times$ 3in. $\times \frac{1}{2}$ in. tee irons, then the thickness t will be, the horizontal area of 4 ft. length of web plus that of two tee irons divided by 48 in., that is $\{\frac{1}{4} \times 48 + 2 \times$

4·5 } ÷ 48 = 0·4375 ins.—*f* the working strain is 5 tons per square inch,—

$$d=\sqrt{\frac{w.l^2}{48.t.f.}}=\sqrt{\frac{44{\cdot}57\times 27{\cdot}5}{48\times 0{\cdot}4375\times 5}}=\sqrt{11{\cdot}673}=3{\cdot}41 \text{ feet.}$$

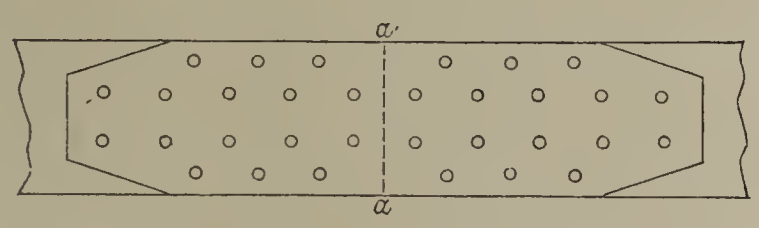
We can now determine the requisite area of flanges and weight of the girder—$w=1{\cdot}62$ tons.

$$\frac{w.l^2}{8.d.5}=\frac{1{\cdot}62\times\overline{27{\cdot}5}^2}{8\times 3{\cdot}41\times 5}=8{\cdot}98 \text{ square inches area.}$$

This will be the nett area of the bottom flange and the gross area of the top flange. Taking only the horizontal limbs of the angle irons as effective, let them be 3 in. by 3 in. by ½ in., then the two limbs will give for the top flange 3 sq. in. area, leaving 6 to be made up by a plate 12 in. wide by ½ in. thick.

In the bottom flange the angle irons will afford a nett area of 2·25 sq. in., leaving 6·75 sq. in. to be made up by a plate 15 in. wide and ½ in. thick, which after deducting two ¾ in. rivets leaves the required area. The web will be ¼ in. thick, with stiffeners of tee iron 6 in. by 3 in. by ½ in. thick, every four feet with packings under them to save joggling them over the angle irons. The total depth of the girder (3·41 ft. inside the angle irons) will be, 3 ft. 7 in., the web being 3 ft. 6 in. in depth. Two cover plates, one top and one bottom will be required. The number of rivets on each side of the joint will be in the top $\frac{6}{\cdot 44}=14$, or 7 in. each row, making the whole length of cover plate, at 4 in. pitch of rivets 4 ft. 8 in. The number of rivets in the bottom flange cover $=\frac{6{\cdot}75}{\cdot 44}=16$, on each side of the joint, these may be zigzag as shown in Fig. 16, the width

FIG. 16



of the flange allowing this to be done without reducing its strength. The length then of this plate will be 3 ft. 4 in. The total weight of the girder will be as follows:

Top flange plate and cover	32 ft.	2 in.	at 20 lbs. per ft.		643 lbs.
Bottom „ „	30 „	10 „	at 25	„	771 „
Web plate	27 „	6 „	at 35	„	963 „
Angle irons.....	110 „	0 „	at 10	„	1100 „
Tee iron stiffeners	41 „	0 „	at 15	„	615 „
Packings under do.	36 „	0 „	at 10	„	360 „
Rivets.....				5 per cent.	222 „
					„
					4674 „

Which is equal to 2·08 tons;—less than that assumed above, but we did not then know the exact depth. Calculating it, however, for the depth now used, our table gives 2·1 tons as the proper weight, but the difference on the whole load is too insignificant to require any alteration in our sectional areas.

We will now take the three girder construction, then with 14 feet clear width, and girders 2 ft. 6 in. wide, the length of each cross girder will be 16 ft. 6 in. The maximum moment of strain due to the live load will be: 8×5·75 =46 ft. tons, equivalent to the strain produced by an uniformly distributed load equal to,

$$W=\frac{8\times M}{l}=\frac{8\times 46}{16{\cdot}5}=22{\cdot}3 \text{ tons.}$$

The weight of ballast and floor plates will be, the girders as before being 4 ft. apart, 16.5×4×72=4752 lbs.=2·12 tons, making the useful load 24·42 tons, the weight of the girder we will assume at ·045 tons per lineal foot=.74 ton.

$$d=\sqrt{\frac{w.l^2}{48.t.f}}=\sqrt{\frac{1.52\times 16.5^2}{48\times 0.4375\times 5}}=\sqrt{3{\cdot}94}=1.98(\text{say})2\text{ft.}$$

The flange area required will be,

$$\frac{w.l^2}{8.d.5}=\frac{1.52\times 16.5^2}{8\times 2\times 5}=5.17 \text{ square inches.}$$

The top flange may consist of two angle irons 5 in. by 3 in. by ½ in. thick, and so also may the bottom as there will be no rivet holes to deduct from the horizontal limbs,—the web being ¼ in. thick and stiffeners arranged as before, the weight will be:—

	ft.	in.	lbs. per ft.	lbs.
Angle irons forming top and bottom flanges	66	0	at $13\frac{1}{5}$	=880
Web plate	16	6	„ 20	=330
Tee iron stiffeners ...	11	6	„ 15	=173
Packings under do. ...	9	0	„ 10	= 90
Rivets			5 per cent.	= 73
				1546

Making for the two girders 3092 lbs.=1·38 tons as against 2·08 tons in the last case.

If we use a distributing girder with the long cross girder, the weight of the flanges of the latter will be reduced by about 655 lbs., but there will be 252 lbs. to allow for distributing girder, hence the total weight will be brought down to 1·9 tons, thus showing a considerable disadvantage as compared with the short girder system.

Where we are limited as to depth the economy of the latter will of course become much more manifest.

We will now pass to the consideration of the main girders, but, in the first place, will fix upon a settled load per superficial foot for ballast, permanent way, floor plates, and cross girders, as it will be convenient in making comparisons to keep to one standard in this respect.

For the long cross girders the dead load referred to will be assumed as 112 lbs. per superficial foot, and for the short girder 96 lbs. per superficial foot.

The live or running load will be taken at 1·5 tons per lineal foot per line of way, the strains produced by a train of locomotive engines and tenders of the heaviest type at

present in use, being equivalent to those corresponding to that load.

Taking a fixed span of 300 ft. clear under these loads, and basing all our working strength on the factor of safety 4·4, we shall arrive at conclusions as to the relative economy of the different systems of construction.

It may be as well to explain the reason for taking this factor, which at first sight appears anomalous.

Girder iron is scarcely ever required by Government to sustain a tensile strength exceeding 22 tons per sectional square inch, and this is, moreover, a quality easily obtained, and dividing by the Board of Trade allowance for working strain we have $\frac{22}{5}=4.4$ as the factor of safety which is really in common use.

All members of the structures which act as struts will be treated as columns calculated by Professor Gordon's formulæ.

In the first place we will take the lattice girder type, and commence by examining the conditions under which the advantages of this form of construction should become conspicuous.

It is obviously impossible to construct a theoretically correct plate web, for at the centre of the space its thickness would vanish. When we say "impossible," we of course imply *practically* impossible, for there are practical limits below which we cannot reduce the sizes of the metal forming bridge structures without endangering their stability and endurance.

We may, however, by adopting the triangular or lattice form of construction so aggregate or sum up the strains and localize them that theoretical areas may be found practically applicable, but on the other hand we have to remember that lattice bars cannot be reduced below certain scantlings, and in fact up to about 60 feet span it will be found practically most economical to use plate girders; this strictly does not concern us in these articles, but is mentioned as a collateral illustration.

Now a plate web may be regarded as consisting of lattice bars, in which the lattice bars are so widened as to touch each other and so become continuous, and proceeding from this supposition we find that where a close lattice is not economical an open one may be, but again another point comes up, that as the lattice becomes more open so the compression elements become weaker, and in this connection some curious points arise. May it not be said, for instance, that the top flange of the girder is a continuous column in its action throughout its length? It is held from crippling in one direction by the web, but laterally if it be not cross braced from girder to girder it has only its breadth upon which to rely. If it were possible to have an element in compression so constituted as to be perfectly straight and and absolutely homogeneous, and exactly equally strained on every part of its cross section, there would be no reason why it should fail by any other way than the crushing of its molecules, but this state of affairs cannot be brought about, and the column and cognate elements will fail in the first place by bending, and the longer the element the more readily will it bend. When it once deviates from a straight line, if the amount of such deviation be ascertained, the bending strain upon the element may be calculated, and this strain will be greatest about the central part, the strain increasing from the ends, therefore we should make a column stronger in the centre than towards the ends, and, in fact, treat the formula as applying to the centre section only, unless we modify it in some such manner as the following.

For the sake of simplicity let us take the case of a plain, circular, hollow cast-iron column, having a length of 20 ft. and a diameter of 1 ft. Commencing at one end and determining the breaking strain at various sections, as if those *were the centre sections of shorter columns*, it appears to us that we should arrive at a more logical way of determining these elements than any that are now usually adopted, and a consideration of this matter may in some other respects lead to valuable conclusions. If $B.W.=$ equal the breaking weight per sectional square inch and $W=$equal the ratio of the length to the diameter, Gordon's rule is; for cast-iron columns, expressed by the formula

$$B.W.=\frac{36}{1\times\frac{r^2}{400}}$$

The first section, say 1 ft. down, will be regarded as at the centre of a column only 2 ft. long; the next one, say, 2 ft. down as the centre of a 4 ft. column, and so on. The results will be as follows for the different lengths:—

1 ft. down from the top of column, or up from the bottom,			$B.W.=$	35·64 tons
2 ft.	,,	,,	,,	34·61 ,,
3 ft.	,,	,,	,,	33·02 ,,
4 ft.	,,	,,	,,	31·03 ,,
5 ft.	,,	,,	,,	28·80 ,,
6 ft.	,,	,,	,,	26·47 ,,
7 ft.	,,	,,	,,	24·16 ,,
8 ft.	,,	,,	,,	21·95 ,,
9 ft.	,,	,,	,,	19 89 ,,
10 ft.	,,	,,	,,	18·00 ,,

The sectional areas should therefore be varied to suit these figures.

This same principle may of course be applied as easily to long struts as to the ordinary columns, and in some cases may be worth doing for the metal it saves. The top member of a triangular girder is generally regarded not as one continuous strut, but as a series of consecutive short struts terminated at either end by a joint, in which case the closer the triangulation the greater will be the working strength of the material.

In a plate or close multiple lattice-webbed girder the flange being *tied down its centre* by the web, any lateral deviation from a straight line must be accompanied by a buckling of one or other edge of the flange, and to prevent this, and therefore add to the general strength of the element,

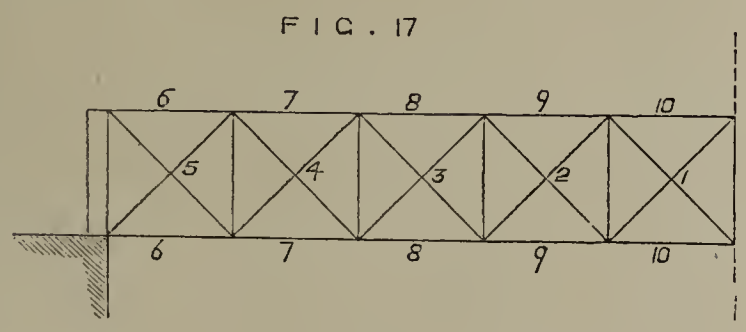
stiffeners should be used at pretty frequent intervals, and the outer edges of the flanges stiffened by longitudinal angle irons, unless the top flanges are of a box section, which at the present time is not often the case, in fact of late years this point of lateral stability of flanges does not seem to receive at the hands of engineers as much attention as it merits.

To sum up the whole matter as briefly as possible in regard to the strength of a compression flange, we require to tie and brace it as closely as possible so as to hold its parts in the best position to resist the direct compressive strain which is normal to it, and practically reduce its effective length as a column to the lowest value.

We will now assume that we have a double line of railway to carry over a bridge 300 ft. span, there being two main side girders on the triangular girder principle, having a double series of triangles, with the bars at an angle of 45 degrees to the horizon. Let the load be carried on the bottom flanges and the depth be 1-10th of the span or 30 ft., between centres of gravity of top and bottom flanges.

Each girder will have to carry one line of railway and half the platform, so its load will be, running load 1·5 tons per lineal foot and dead load, the clear width being 25 feet, 12·5 × 112lbs. = 1400lbs. = 0·625 tons, making a total useful load of 2·125 tons, or a total useful load of 637·5 tons, whence the assumed weight of the main girder itself will be (the factor for the span to depth ratio of 10 being for uniform strain on flanges ·00167) 637·5 × ·00167 = 1·065 tons per foot run. The total *dead load* per lineal foot will 1·69 tons.

FIG. 17



The diagram (Fig. 17) shows one half of the main girder. The top and bottom flanges are to be trough shaped in cross section, and the struts stiffened laterally by consisting of two bars braced together or joined by a solid web according to the section we require.

The strains will in amount be the same for the tie and strut in any pair crossing each other as the load is distributed between the two series of triangles by the vertical suspenders. The maximum strain on any strut or tie is when the live load is approaching that bar, hence we must calculate the inclined bars for rolling load, and the flanges for a full load on the girder in order to obtain the maximum strains to which it will be subjected. The floor is supposed to be properly furnished with distributing girders so as to render the load on the main girders practically uniform.

The distance from joint to joint of the main flanges with the diagonals is 30 feet, hence the dead load on each apex for one series of triangles will be equal to $\frac{1·69 \times 30}{2} = 25·35$ tons, and the live load $\frac{1·5 \times 30}{2} = 22·5$; the strains on the bars will therefore work out as under:—

No. of Bar.	From dead load.	From live load.	Total in tons.	Area of Ties square inches.
1	5× 25 · 35 × 1·414 = 17·92	22·5 × 5 × ·3 × 1·414 = 47·72	65·64	13·13
2	25 · 35 × 1.5 × 1·414 = 53·76	22·5 × 6 × ·35 × 1·414 = 66·81	120·57	24·11
3	25 · 35 × 2·5 × 1·414 = 89·60	22·5 × 7 × ·4 × 1·414 = 89 08	178·68	35 73
4	25 · 35 × 3·5 × 1·414 = 125·44	22·5 × 8 × ·45 × 1·414 = 114·53	239·97	47·99
5	25 · 35 × 4·5 × 1·411 = 161·28	22·5 × 9 × 5 × 1·414 = 143·16	304·44	60·89

It must also be noticed that as the load comes on the bridge, the *nature* of the strains on the bars 1 may become reversed, the tie acting as a strut and the strut as a tie when the load has only reached the apex next to the centre. Let us see how this will affect our calculations in the present case, it being understood, however, that in the two centre bays of the girder containing bars 1, both tie and strut bars are to be cross braced to meet the contingency referred to.

In this case it will be to *deduct* from the strain due to the dead load, its amount will be = 22·5 × 4 × ·25 × 1·414 = 31·81 tons and 17·92 — 31·81 = — 12·82 tons, which will be tension on the (ordinary) strut and *vice versâ*.

The multiplier 1·414 is the cosecant of the angle made by the ties and struts with the horizon, and is the ratio of the strain on any diagonal bar to the load producing such strain.

We must see whether the compressive strain will require a greater area than the tensile, and act accordingly. The bar 1, taken as a tie requires 13·13 square inches which may be made up by two plates 12 in. wide by ⅝ in. thick, giving an area of 13·12 square inches after deducting two ¾ in. rivet holes which will be required for the connecting bracing between the bars. In the centre of their length where they cross, the bars may be connected by 1¼ in. bolts passing right through all four of them, and having a proper pipe washer in the centre so that the nuts may be tightened up without bending the tie bars, thus the length of member acting as a column will be reduced to one half the total effective length.

The depth of the girder being 30 ft. the length of one tie bar between centres will be 30 × 1·414 = 42·44 ft., which number will also be the ratio of length to diameter; hence applying the formula with our factor of safety, we have for working strain per sectional square inch;

$$\frac{19}{1 + \frac{(21·21)^2}{900}} \times \frac{1}{4·4} = 2·88 \text{ tons per square inch.}$$

So the safe strain in compression would be 13·12 × 2·88 = 37·78 tons, but we have seen above that the compression will not exceed 12·89 tons, hence there is ample provision in this case.

The weight of the ties may now be determined, allowing in each case two inches area for rivet holes. The total

length of each tie bar is to be taken for a depth of 32 feet; $32 \times 1{\cdot}414 = 45{\cdot}248$ feet. Summing up the areas from the table (adding two inches to each), we have for the half girder, 91·85 sq. in., say, from the whole girder 184 sq. in., making the weight $184 \times 45{\cdot}248 \times 3{\cdot}33$ lbs$=27750$ lbs.$=$ 12·4 tons.

We must now determine the struts. These will be made wider towards the points of support, hence we will take an average working strain; that at the centre is 2·88 tons per sq. in.

Let the struts No. 5 be each of bars 2 ft. wide, then the ratio for column length will be $\frac{42{\cdot}42}{2 \times 2} = 10{\cdot}60$ and the working strength

$$\frac{19}{1 + \frac{(10{\cdot}6)^2}{900}} \times \frac{1}{4{\cdot}4} = 3{\cdot}83 \text{ tons per square inch,}$$

the average of these will be 3·35 tons per sectional sq. in., hence by proportion we can find the weight of the struts from that of the ties. It is not usual to deduct *rivet holes* in compression, but *bolt holes* should be deducted, as bolts never truly fit the holes, there being in fact about 1-32nd inch purposely left all round the bolts in order that they may be entered without difficulty, hence we shall allow the same for the struts in proportion as for the ties, for the bigger ones will naturally suggest the use of larger bolts at their places of intersection.

The weight of the struts will be,

$$12{\cdot}4 \times \frac{5}{3{\cdot}35} = 18{\cdot}5 \text{ tons.}$$

There is also the weight of the bracing between the bars of thestruts; this may be made of flat iron 3 in. wide by ½ in. thick, and so bent that its total length will be twice that of the struts, between flanges, with the two central ties added, so it will be

$2 \times 12 \times 28 \times 1{\cdot}414 = 950$ ft. and 950 ft. $\times 5$ lbs.$= 4750$ lbs.$=$ 2.12 tons.

We now come to the top and bottom flanges, in the latter we shall allow an addition of 25 per cent. for rivet holes.

These elements must be calculated for a full load all over the bridge, which being 3.19 tons per lineal foot, will be $\frac{3{\cdot}19 \times 30}{2} = 47.85$ tons. The strains on the pieces 6, etc., will be as follows:—

On piece 6	$47{\cdot}85 \times 4{\cdot}5 = 215{\cdot}32$ tons.	
,, 7	$215{\cdot}325 + 47{\cdot}85 \times 7{\cdot}0 + 47{\cdot}85 =$	598·12 tons.
,, 8	$598{\cdot}12 + 47{\cdot}85 \times 5{\cdot}0 + 47{\cdot}85 =$	895·22 ,,
,, 9	$895{\cdot}22 + 47{\cdot}85 \times 3{\cdot}0 + 47{\cdot}85 =$	1086·62 ,,
,, 10	$1086{\cdot}62 + 47{\cdot}85 \times 1{\cdot}0 + 47{\cdot}85 =$	1182·32 ,,

In determining the sectional areas, as we shall have *no bolts* in the top flange there will be no deductions to make, and the working strain will be found in a similar manner to that used above for the struts.

From apex to apex the flange is 30 feet long, and its depth is to be 2 feet, hence the working strain per sectional square inch will be, the ratio being 15—

$$\frac{19}{1 + \frac{(15)}{900}} \times \frac{1}{4{\cdot}4} = 3{\cdot}45 \text{ tons.}$$

As we have to allow 25 per cent. for rivet holes in the bottom flange, we shall obtain the areas by dividing by 4 instead of 5 tons per sectional square inch: in the two flanges they will be as under:—

	Bottom Flange.	Sq. in.	Top Flange.	Sq. in.
Piece 6	$\frac{215{\cdot}32}{4}$	$= 53{\cdot}83$	$\frac{215{\cdot}32}{3{\cdot}45}$	$= 62{\cdot}41$
,, 7	$\frac{598{\cdot}12}{4}$	$= 149{\cdot}53$	$\frac{598{\cdot}12}{3{\cdot}45}$	$= 173{\cdot}36$
,, 8	$\frac{895{\cdot}22}{4}$	$= 223{\cdot}80$	$\frac{895{\cdot}22}{3{\cdot}45}$	$= 259{\cdot}48$
,, 9	$\frac{1086{\cdot}62}{4}$	$= 271{\cdot}65$	$\frac{1086{\cdot}62}{3{\cdot}45}$	$= 314{\cdot}96$
,, 10	$\frac{1182{\cdot}32}{4}$	$= 195{\cdot}58$	$\frac{1182{\cdot}32}{3{\cdot}45}$	$= 342{\cdot}70$

This will give as the sum of the areas in all the segments of both flanges 4094·6, say 4095 square inches, corresponding to a weight of

$$30 \times 4095 \times 1{\cdot}414 = 173{,}710 \text{ lbs.} = 97{\cdot}54 \text{ tons.}$$

There are next the cover plates over the joints to be provided for. Let the plates be assumed as all 15 feet long (about) in the flanges, the ties and struts being made in three lengths each, the weight of covers for the flanges will then be found to come to 20 per cent. of the plates, and those of the diagonal bars about the same, making for the total weight of cover plates 21 tons. Each end pillar of the girder must support in compression the load brought upon it by the tie No. 5, that is, one-fourth the total load on the girder. The width of the pillar is 3 feet, its height, effective, 31 feet, hence its ratio of length to diameter $\frac{31}{3} = 10{\cdot}33$. The working strength per square inch will therefore be,

$$\frac{19}{1 + \frac{(10{\cdot}33)^2}{900}} \times \frac{1}{4{\cdot}4} = 3{\cdot}86 \text{ tons.}$$

The horizontal sectional area of each pillar will be,

$$\frac{957}{4 \times 3{\cdot}86} = 62 \text{ sq. in. (nearly),}$$

making 124 square inches for both ends; $124 \times 32 \times 3{\cdot}33 = 13{,}226$ lbs. $= 5{\cdot}90$ tons. Add for top and bottom plates and cover strips 0.9 ton, making 6.8 tons for the ends. The total weight of the girder may now be summed up as under:—

The uprights, 32 feet long by 12 inches area, will weigh, $32 \times 9 \times 12 \times 3{\cdot}33 = 11{,}520$ lbs. $= 5{\cdot}14$ tons.

Weight of flanges	77·54	tons.
,, ties	12·40	,,
,, struts	18·50	,,
,, do. bracing	2·12	,,
,, cover plates	21·00	,,
,, end pillars and uprights ...	11·94	,,
	143·50	,,
Rivets 5 per cent.	7·17	,,
	150·67	,,

It will be observed that this works out very much lighter than the assumed weight, and it will also appear so in large bridges, because the strains are so heavy that we have not any waste metal in the structure, and the more especially does this apply in the case of the web, which in girders of moderate size must always be in excess of that required by the calculation, and the tables used were designed for moderate sizes.

We shall not, however, require to make any allowance for this reduction in load, as by keeping the same load and dimensions for all examples the comparisons will be correct.

(*To be continued*).

THE CHANNEL TUNNEL.

(*Continued from page 240.*)

DIFFERENCES of opinion are sure to arise between projectors of rival schemes, but when these have reference to a work of such magnitude as the proposed Channel Tunnel, whose successful completion would confer immortality upon all connected with it, one would think that each would endeavour to meet the other, or, at all events, avoid such asperities as are fatal to future co-operation. But it is curious to observe how singularly prone have been those interested in this work to tread upon each other's toes. In 1857 Lord Palmerston, who did not believe in the thing, snubbed the Prince Consort, who supported it "with truly enthusiastic sympathy," to the visible horror of the courtly M. Thomé de Gamond. This gentleman, the father of the modern enterprise, took an early opportunity of apologizing to the Prince for having been the cause of the "disgraceful incident," but His Royal Highness pleasantly passed over the affair as "one of the frequent sallies in which Pam dealt." In 1868 Mr. Hawkshaw roundly charged Mr. Brunlees with a breach of professional etiquette in having associated himself with other engineers to seek for a concession for the work when he, Mr. Hawkshaw, had been for two years engaged in operations. These gentlemen appear to have become reconciled, but in 1873 Mr. Hawkshaw refused to work with Mr. Low, and distinctly informed that gentleman that if Lord Richard Grosvenor's Committee re-appointed him, Mr. Hawkshaw would retire. This was hard measure for Mr. Low who, six years earlier, had conceived the idea of two separate tunnels, his view being that, as with the upcast and downcast shafts in a colliery the one ventilates the other by producing draught, so, horizontally, these two tunnels would answer the same purpose. After considerable difficulty he succeeded in obtaining an audience from the Emperor Napoleon III. and so convinced that enlightened monarch of the practicability of his scheme, that the latter observed "I should be glad to see it done. As soon as your prospectus is ready send it to me, and I will lay it before my Ministers, and do all I can to support it." A year later we find a company in existence with Lord R. Grosvenor as Chairman, and the latter writing to Mr. Low, saying, "I assure you I have lost no confidence in your scheme. I shall be glad to do all in my power to set it going, as I have great faith in it." But the prospectus which appeared afterwards bore only the names of Sir John Hawkshaw and Mr. Brunlees as Engineers. Under these circumstances it is not surprising that we now see Mr. Low an active and valued coadjutor of Sir Edward Watkin in the rival project.

The prospectus in question being the first authoritative publication of an apparently matured scheme, some extracts therefrom will aid in elucidating subsequent events and in explaining certain phases of adverse criticism. The Committee was highly influential, consisting of Lord Richard Grosvenor, Mr. William Hawes, Sir Nathaniel and Mr. Alfred de Rothschild and Mr. Forbes, Chairman of the London Chatham and Dover Railway. It proceeded :—

"The object of the Company is to sink a shaft at St. Margaret's Bay near Dover, and to drive a short driftway therefrom under the sea, in the direction of works near Calais to be executed cotemporaneously by the French Tunnel Company, to determine more exactly than can be done by the trial borings already made, the time and expenditure required to complete a Railway Tunnel between England and France. These preliminary works will form part of the Tunnel and may be finished within eighteen months.

"The French Tunnel Company is empowered by Act of Assembly to unite with an English Company for the execution of the Tunnel. The first Capital of the French Company is also £80,000, and has been subscribed by the Company of the Chemin de fer du Nord, the Messrs. Rothschild frères, of Paris, and a small body of Capitalists.

"Of the £80,000 now required by the English Channel Tunnel Company, Messrs. N. M. Rothschild and Sons, and the London, Chatham, and Dover Railway Company, have each consented to subscribe £20,000, conditionally on the balance of £40,000 being provided, of which sum above £15,000 is already subscribed.

"It is difficult to make an adequate estimate of the amount of the passenger and goods traffic to and from England and the Continent when railway communication shall be established. The passenger traffic is fully 450,000 persons per annum, increasing yearly at the rate of about 5 per cent.; and when the special inconveniences attending the present painful and expensive route are removed and replaced by the comforts of modern railway travelling, with a frequent, regular and uninterrupted service, the number of travellers will, it is universally admitted, increase at least threefold. The goods traffic amounting in value to about £75,910,000 per annum, and employing a tonnage of about 12,000,000 tons, must to a great extent be carried by the quickest and most direct route, especially when it can be so conveyed with certainty and punctuality, and without change of carriage, to and from all parts of England and the Continent."

The first paragraph of the above contained the apple of discord which has never yet been removed. Engineers and geologists alike declared that the grey chalk was the sole formation through which the Tunnel could be driven, but Sir Edward Watkin, backed by his engineer, Mr. Francis Brady, unhesitatingly affirmed that St. Margaret's Bay was the wrong place to commence it. In May, 1874, Mr. Brady reported to that effect, and Sir Edward declared his opinion, from which he has never swerved, that this chalk should be followed from the point where it crops out near Folkestone, working always, to use their own phrase, "in the dry," the old grey chalk, or Craie de Rouen. This is described as "an amalgamation of clay and clalk, and therefore impervious to water percolation." They never disguised their objections to the plan of Sir John Hawkshaw, who is alleged to have given utterance to an acknowledged geological error. He said "the grey chalk is not reached on either shore without going through the white chalk," whereas it is well known that the former crops out near Folkestone Junction. His plan was to put down pumps with 2,000 horse-power to work them, but his opponents assert that he would have to pump the sea on one side, and the water of the whole country on the other. And even when Lord Grosvenor's Company so far modified its plan as to begin at Fan Hole, and end at Biggin-street, in Dover, it was stated to be open to the same objections, and Sir E. Watkin's Company has actually acquired land at Fan Hole for the purpose of such works as shall demonstrate the justice of these assertions. "If," says Sir Edward, "you have to pump the land drainage or the sea, or to timber your structures in the clay, the construction of the tunnel is impossible. The enormous cost would render it out of the question. The enormous time would consume a generation." On another occasion, having read an article in a Society paper in which his project was called "an aquarium," Sir Edward Watkin pleasantly retorted by designating the rival affair as "an aviary," with Mr. Labouchere as the hawk, Mr. Parkinson Sharp as the vulture, Sir Drummond Wolff as the owl, and Lord Richard Grosvenor as the dicky-bird. These little amenities are all very well if people will accept them in a Pickwickian sense, or as "one of Pam's sallies," but when it is remembered that this sort of thing has been going on for the past eight or ten years, no one will be surprised that considerable acrimony has been gradually developed. Sir Edward Watkin laughs his rivals to scorn, and Lord Richard Grosvenor declines his overtures with aristocratic hauteur, and the culmination seems to have been reached in May last when the former addressed the latter as follows:—

"My Lord. I have here before me what purports to be a copy of a letter from your Lordship to Mr. Forbes, the Chairman of the London, Chatham and Dover Railway, dated in May of last year: The copy runs as follows: 'Mr. Bellingham tells me that if the London, Chatham and Dover will go with him, he could start the tunnel in their interests and not in the interests of the South Eastern Railway, as is now being done. Are you disposed to go into it? as, if so, we could start afresh; but if you do not feel disposed to do so, please let me know, as it would be of no use our wasting any more time and trouble if that is your decision.'

"My object in troubling you—apart from my duty to advise you that I have such a document—is to inform you that all our work has been done with a view as much to the interests of the London, Chatham and Dover, as of the South Eastern; and when last year we proposed to deposit our Bill, terms of union and access were proposed to Mr. Forbes, to which, however, we have had no definite reply. We have sought no monopoly, and it is not our fault if united action failed by the refusal on your part, and that of your friends, to adopt any plan but your own.—I have the honour to be, my Lord, Your faithful Servant, E. W. Watkin."

Lord R. Grosvenor replies a week later:—"I have the honour to acknowledge the receipt of your letter of May 26th, in which you quote a portion of a letter from me to Mr. Forbes dated in May of last year. Never having been able to obtain your co-operation in any way, I naturally have turned to Mr. Forbes and the London, Chatham and Dover, and have felt always at perfect liberty to do so. It is obvious to everyone that both lines, the South Eastern Railway and the London, Chatham and Dover, must have equal powers through the tunnel by whomsoever it is made, and I fail to see how a tunnel, the entrance to which is on the South Eastern Railway west of Dover, can be much in the interests of the London, Chatham and Dover. I can only repeat in this letter what I have said in public, that one of the main points which we always requested Sir John Hawkshaw to keep in view was the accessibility of both lines, the South Eastern Railway and the

London, Chatham and Dover, to the tunnel. That always has been kept in view by him and myself, and I consider is fully met by our deposited plan.—I am, Sir, yours obediently, RICHD. GROSVENOR."

Sir Edward promptly fires his next shot. "In thanking you for your note of the 3rd, I hope you will pardon me if I point out that your 'deposited plan' merely shows works extending from 'Fan Hole,' on the coast, to 'Biggin Street,' in the town of Dover. You have deposited no plan nor made any money deposit for anything more. Thus you propose no connection whatever with either London, Chatham and Dover, or with South Eastern. You will, I should hope, admit (1) that a tunnel should, nay, can only, in practice, be made under the most favourable of the existing geological conditions; and (2) that it should form part of the shortest routes between London and Paris. We believe that we are complying with the first condition; and the compasses will show that we are obeying the second, while our whole project is entire and consecutive, and not a detached portion only of a project. In addition, the proposal made last year to the Chatham provided for them not only a shorter line to London, but an alternative route under existing legislation. It is true that I could not help you in 1874-5, because I knew that the proposal to go to St. Margaret's Bay was an error, an error now admitted by your adoption of the site of Fan Hole, and if I recollect rightly, Sir Daniel Gooch and Mr. Laing declined also. But you had the aid of the names of Mr. Forbes and of the Messrs. De Rothschild on your prospectus at that time, and surely you did not need my humble help. Why did you not raise your money and go on?"

No wonder that with this the correspondence ceased. We give it as it explains the attitude of the belligerents better than volumes of description. There was clearly but little hope of repairing the breach when the chiefs addressed each other with such bitterness of recrimination. But had there been a chance of this it must have been dispelled by Lord Alfred Churchill, who at the extraordinary general meeting of the Submarine Continental Railway Company, Limited, held at the Cannon Street Hotel, on August 17 last, deliberately charged Lord Richard Grosvenor with using his influence as Treasury Whip to cause the Board of Trade to take harassing action against the Company. Lord Alfred enquired "if this is the same Lord Richard Grosvenor who is a Lord of the Treasury? because, if so, it is his business to act as Government Whip, and he has carefully to bid up for the support of Government measures. It is a well known fact that Sir Edward Watkin voted against the Government on a particular occasion, and the following morning he received notice from the Board of Trade to discontinue his work at the tunnel." This is plain speaking with a vengeance, and with so pungent an anecdote we conclude that portion of our task which relates to the Channel Tunnel Company, Limited, accepting the statements contained in Sir Edward Watkin's last letter as to the progress that Association has made.

The Submarine Continental Railway Company, Limited, may be called a creation of the South Eastern Railway Company, with whom it has entered into an agreement of which the following are the principal features. By the South Eastern Act of 1874 that Company was empowered to employ £20,000 towards the cost of works in connection with the Tunnel, and by the Act of 1881 they were further empowered to acquire certain lands for the purposes of experimental borings and other works. The lands were bought, works constructed, plant and machinery provided, and an undertaking entered into that the South Eastern Company should complete the experimental tunnel to a length of 1,000 yards from the bottom of the shaft at Shakespeare Cliff and provide passing places at the end of each 500 yards. This land, shafts, and the benefit of all contracts were handed over to the Tunnel Company on March 31 for the sum of £30,000 in cash and £20,000 in fully paid up shares. The capital of the Tunnel Company—£250,000—was all taken up, a large part at a premium, and, the South Eastern Company having loyally performed 1,100 yards of tunnelling within the prescribed time, the Tunnel Company had by July 15 completed a distance of 2,015 yards of seven-feet bore, at a total expense of £42,700, besides 880 yards of submarine gallery from Abbott's Cliff and various other points. Dr. Siemens has succeeded in illuminating the works with the electric light. Colonel Beaumont has demonstrated that compressed air at one and the same time performs the boring, and perfectly ventilates the works. The Company commenced operations in the light of day, with the full knowledge of every department of Government, and have continued them with an amount of energy and skill which entitles them to the highest public consideration and respect.

Under these circumstances, if they are to be stopped now, why was not the brake applied before? Is it not monstrous that a company represented on the register by 661 shareholders possessing an aggregate capital of a quarter of a million sterling—sufficient to complete their experiment, and willing to lose it if that experiment fails—who have already expended one-fifth of their capital, should be prevented from proceeding with their useful labours on the strength of opinions which are nothing but hysterical? It is impossible to see how the Board of Trade can justify its inconsistency. This hole was not dug in the dark. On the contrary, Mr. Chamberlain was communicated with and a proposal made to him that this company should make and prepare for traffic one mile of the tunnel, and that the Government should then complete the eleven miles or thereabouts remaining to be constructed to meet the portion commenced in France. Mr. Chamberlain on behalf of the Board of Trade replied as follows on September 16, 1881:—

"We do not think that the project is one which should be any exception to the general rule by which in this country such enterprises are left in private hands. We shall not, therefore, recommend either that the Government should

undertake the work, or that it should give State assistance in any form to the realization of this idea; at the same time we are anxious that no officialism or red-tape should be allowed to prevent, or even to delay, the undertaking, if private individuals are willing to go on with it. We have no preferences or prejudices in reference to the different schemes which have been suggested. We have to satisfy ourselves first that no national interest is endangered by such a work as is proposed, and, assuming that this is satisfactorily established, then we have to consider the conditions which it may be necessary to impose, and to see that the position selected is the most suitable for any requirements which may have to be insisted on. We are also of opinion that the Tunnel if made cannot be allowed to afford a monopoly of communication to any one Company."

This is intelligible, and, inasmuch as the question of "national interest being endangered" had virtually been provided for in Mr. Farrer's letter to the Earl of Derby in 1874 (The *Railway Engineer*, p. 237), there was absolutely nothing in Mr. Chamberlain's communication to lead the projectors to suppose that their operations would be interfered with on that ground. A month later Mr. Chamberlain, having consulted his colleagues, adds: "As I anticipated, the Government are not inclined to take any active share in promoting or carrying out the project of a Channel Tunnel. They consider that their duty requires them to see, in the first place, that no national danger is involved in such an undertaking; and, in the second place, that if it should be carried out, national interests should not be sacrificed to a private monopoly. With this double object a committee has been appointed, as you are aware, to consider the whole case, and will report to the Government whether the proposal may be safely entertained, and, if so, what conditions should be imposed upon any individuals or company charged with the enterprise. No time will be lost in arriving at a decision, which will be communicated to you as early as possible." The committee referred to consisted of Mr. Farrer, Secretary to the Board of Trade, Admiral Phillimore and General Smith, who duly examined witnesses. That they arrived at some conclusion we know, because their report was presented to Parliament in August last. But fifty weeks have elapsed since "no time will be lost in arriving at a decision," and not yet has that decision been "communicated" to Sir Edward Watkin or anybody else. It is not yet in print. We say unhesitatingly that Mr. Chamberlain's first letter was a direct encouragement to proceed. It bore the stamp of political wisdom and fair dealing; and the second contained no word to engender doubt in the minds of the projectors. The after appointment of a Military Commission was caused by the sudden utterances of alarmists, and its report will, we assume, be appended to the other. But it was appointed too late to save the expenditure of the Company's fifty thousand pounds. We are far from saying that the consideration of that or any other conceivable sum is to interfere with our national security, but let us know with some degree of reason that our national security is really in jeopardy before you interfere with the progress of a work which you have promised neither to prevent or delay, and before you sacrifice the money of others who have expended it under the ægis of your official sanction.

And what are the grounds upon which the stoppage of the works was ordered? We believe ourselves to be acquainted with everything that has been written or said in public on the subject, and have failed altogether to discover any tangible argument that could justify this arbitrary decree. It is no use calling names in a matter so important, and indeed it is impossible to doubt the bonâ fides of many of those who offer to the project the most uncompromising opposition. There is Admiral Lord Dunsany, for example, who has written against it in the *Nineteenth Century*, and spoken with equal ability at the Society of Arts. But when asked for his reasons he *naively* replied that those with whom he acted were rather against entering into details at present. Herein lies the difficulty with which those in favour of the Tunnel have to contend. Their opponents deal in more or less eloquent generalities, appealing to the easily excited passion of alarm, which is always contented with the broad statement that a danger exists, and declines altogether to listen to those who deny its existence, or, acknowledging it, indicate the path of safety. Lord Dunsany says that it is a question of principle, and that his party are not going to be led away by little matters of detail which might show that certain fears were more or less groundless. But, consenting to give some reasons, the Admiral referred to the inviolability of our shores, affirming that they had not been invaded for eight hundred years. Sir John Hay, equally opposed to the Tunnel, demurred to this as a matter of history, saying that such things had happened at least eight times since the Roman Conquest. This is the strongest sort of argument we have to meet. No Englishman will presume to entertain a thought other than that of respect for Lord Dunsany and Sir John Hay, but all men are not Admirable Crichtons, and few are possessed of such a combination of qualities as would enable them to distinguish themselves equally in command of the Channel Fleet, and in the Professorial Chairs of History and Logic at a University. In the present case, these gallant gentlemen understand neither each other, their country, or its history. They join issue upon a matter of fact, each being right from a different standpoint, but each arriving at the same wrong conclusion. The invasions in question took place during the existence of the silver streak, but not since the Anglo-Saxon has taken the foremost place in the ranks of progress, civilization, and power. That is the answer to Lord Dunsany. As a matter of fact, our shores have been invaded, and successfully invaded, hundreds of times, if we go back far enough, but never since we have become welded into a compact, homogeneous, and patriotic nation. The silver streak alone never stopped an invader. The invader succeeded against a disunited people, whose insular position delayed for centuries their progress in those

arts for acquaintance with which Continental nations were indebted to facilities of inter-communication that the silver streak denied to us. This talk about the silver streak is becoming a nuisance. That strip of sea, like many other things, is a good servant, but a bad master. Make it subservient to your purposes certainly, but if its existence is to be used as a means for delaying the development of ideas calculated to immensely increase the material welfare of many millions of people, then, in the words of Hamlet, "reform it altogether." The Submarine Tunnel Company offers the opportunity.

It has been said that the close neighbourhood of nations does not always contribute to their friendship. This is true enough, but applicable only to cases where they are too close, and to conditions of semi-barbarism. It is so in some parts of India, and on the Greek and Montenegrin frontiers of Turkey. There is no doubt that great ill-will exists between the inhabitants on either side of the French and German frontier. Possibly the strongest illustration is presented by the unappeasable hostility which existed for ages on our own border-land of the Tweed. But all this refers only to people who live on either side of a line as impalpable as the equator, and meet each other every day. It is altogether inapplicable to the circumstances of two nations who will always be separated by an uninhabitable space of over twenty miles. Kent may have local differences with Surrey as to the sanitary state of the eastern edge of the suburb of New Cross, but will not easily be induced to trouble the authorities of Hertfordshire respecting the disestablishment of the Great Bed of Ware.

There is another force with which the antagonists of the Tunnel will have to count. The various labour organizations have taken the question seriously in hand, and important meetings have been held at Liverpool, Leeds, and other centres of industry, at each of which the interests of the working man have been advocated with the solid sense that usually characterizes his representatives. To a man these are sincerely desirous of peace. They regard war not only with conscientious horror, but with economical dread. Their patriotism is unquestioned. The chief direct interest they can possibly have in the construction of the Tunnel is that it would provide a certain amount of employment for their class, and a desire for work has never yet been stigmatised as a sordid or selfish sentiment. Besides this, they have a belief that doing away with the necessity for transhipment and breaking bulk will have the effect of materially cheapening fruit, fish, poultry, and similar perishable food. But, above all things, they entertain the belief that the interests of peace and goodwill between the peoples of France and England would be immensely served by the execution of the work. They ridicule the idea of invasion, and believe in the power of the manhood of their country to defend it in case of necessity. And on this point it seems to us that no other class is better capable of judging. At Liverpool, after an able and far-sighted address by Mr. George Shipton, the Secretary of the London Trades' Council, a resolution was passed affirming, "That this meeting is of opinion that the construction of the submarine channel tunnel would not form the least danger or injury to this country, but, on the contrary, its completion would be of mutual advantage to both nations, and tend to unite the peoples in the interests of peace and industrial progress." A similar motion was carried at Leeds, and the speakers were practically unanimous in their approval of the project. This unbought and unsolicited support can scarcely be ignored by Mr. Chamberlain, who is himself the representative of an industrial constituency, and we await with some curiosity and much hope the result of the meeting which is shortly to be held in Birmingham on the subject. Mr. Cobden was one of the first to give his voice in favour of the undertaking, and Mr. Bright is not unlikely to support the opinion of his late illustrious friend, and to bring his influence to bear upon his present colleague.

We promised to examine the charge of breach of faith brought against Sir Edward Watkin and his colleagues by the Board of Trade. This was that, in the face of a distinct undertaking entered into on July 5th that no further progress should be made with the works except such as was indispensable for their ventilation and general safety, they did proceed a further and unnecessary distance of seventy yards. The accusation was made in the most public and uncompromising manner in Parliament by the President of the Board of Trade, and in the daily newspapers by the publication of a letter addressed by the solicitors of the Board to the solicitors of the Company. Mr. Brady, the engineer of the latter, who was, of course, the actively responsible officer, met the charge with an affidavit containing a distinct and categorical denial. He described his instructions, which were to give the Inspector, Colonel Yolland, every facility, to place the machinery and staff engaged at the works at his disposal and, if he wished it, to set the whole machinery at work and employ extra hands. To Colonel Yolland he explained what he was doing; that a moderate amount of boring would be done, necessitating turning the machine round so that the air might be allowed to escape and pure air to enter, and to this the Inspector made no objection. Subsequently, being informed that the Board of Trade did not concur in the proposed method of draining and ventilating the works by the existing machinery, Mr. Brady ordered the boring machine to be absolutely stopped, and it worked no more except on the evening and night of August 4, when it was necessary to clear away the mud and water from the heading and to perfect the ventilation in readiness for the visit of Colonel Yolland on the following day. During the whole period Mr. Brady admitted that the machine had been working to a small extent, but only for the purposes stated in the notice to the Board of Trade of July 6. How small this extent was may be conceived from the fact that the whole progress during that time was 36 yards. Colonel Yolland, however, measured it, and pronounced it to be

70 yards. The following correspondence sets that question, at all events, at rest :—

" 147, Leadenhall Street, E.C., 26th August, 1882.

" Dear Sir,—Having reference to your affidavit of the 15th instant, contradicting the sworn testimony of Mr. Brady as to the length of the heading assumed to have been bored between the 15th July and 5th August, we learn from our clients that you have this day measured the experimental works with care.

" We are, therefore, instructed to inquire if you are now prepared to withdraw or modify the contradiction contained in your affidavit.

" We write in the hope that you will now be able to relieve our clients' officer from the implied charge involved in your last affidavit. We are, &c., FOWLER and PERKS.

" Colonel Yolland, Board of Trade."

" Glendair, Jilkley, Yorkshire, 29th August, 1882.

" Dear Sirs,—I have to acknowledge the receipt of your letter of the 26th inst.

" On that day I remeasured the portion of the Tunnel which I had previously measured on the 5th August, and I found that I had incorrectly entered the length measured on the 5th August by one chain (of 100 feet, equal 33 1-3 yards), so that my measurement on the 26th instant agrees with Mr. Brady's.

" I informed Mr. Brady that I had discovered my mistake, and I have reported it to the Board of Trade. Yours, &c., W. YOLLAND.

" Messrs. Fowler and Perks."

The lawyers seemed to think this rather a bald sort of an acknowledgment after all the awful denunciations to which their clients had been subjected through their correspondent's error, so on the 4th ult. they again addressed Colonel Yolland as follows :—

" Dear Sir,—We are obliged by your letter of the 29th August, and are instructed to say that our clients note that you frankly admit the error you unfortunately made, and upon which erroneous statements recent exceptional legal action was founded.

" We should, however, fail in our duty to our clients if we failed to point out to you the serious injustice which your mistake is calculated to inflict.

" The statement contained in your report that between the 15th July and the 5th August the Company had carried the heading seventy yards forward was made without any communication with our clients, or their officers to test its correctness, and was, without any such confirmation or correction, officially made in Parliament by the President of the Board of Trade who, relying upon its accuracy, directed an application to be made to the Court involving the extraordinary proposal to seize the whole properties of the South-Eastern Railway and Submarine Railway Shareholders.

" Our clients feel that the injustice done to them and their officers was aggravated by the fact that after Mr. Brady, Sir Fred. Bramwell, and others had denied the accuracy of your affidavit, you again swore to the truth of the statements which you now admit were wrong. Yours, &c., FOWLER and PERKS."

Colonel Yolland contented himself with simply acknowledging this, and if the atrabilious opponents of the tunnel had exercised similar discretion there would be no more to say on the subject. The Inspector made a mistake, discovered his error, and confessed it like a man. We know none who want to be hard on him except perhaps those clever persons who carry beams permanently in their own eyes, and never allow that they themselves were wrong in their lives. Putting Colonel Yolland's high personal character altogether on one side, had he been the most corrupt of officials, there would have been no use in wilfully making such a mistake as this. It was bound to be found out. But the perverted ingenuity of those who insist upon seeing the reverse of good in everything whose uses they do not understand finds even in this faggot a stick to beat the dog which happens at the moment to be their pet aversion. For example, a daily contemporary, so far from admitting this acknowledgment to be a justification of Mr. Brady and Sir Edward Watkin, discovers therein fresh evidence of their tergiversation, and insists that " any steps the Board may have meditated on the supposition that 70 yards had been excavated are equally applicable and necessary now that it is understood that the actual distance was only rather more than half the total given in Colonel Yolland's report." This is wilfully ignoring the fact that notice was given to the Board that a certain amount of boring was necessary, and that the order of the Court permitted its execution. And surely, when it is remembered that the excavating power of the machine is 100 yards per week, it must be conceded that the performance of only 36 yards in a month conclusively proved that both the letter and spirit of the engagement were honourably kept. It has been insinuated that there was no necessity for further work for the purposes of drainage and ventilation. On this point the public may be contented with the evidence of eminent experts. Sir Frederick Bramwell, an engineer of nearly half a century's standing, says, " I, as an engineer, if I had to act on my own responsibility under the order of the Court of the 5th of July, should have felt that I was strictly within the conditions of the order, which permitted the defendants to execute all further works which might be necessary for the purpose of draining or ventilating the existing works. The mode of draining the tunnel proposed by Mr. Brady is, in my opinion, the only workmanlike and practical method of dealing with the drainage, having regard to the fact that the machinery is situated at the lowest point of the tunnel, where the water naturally collects, and to the fact that it is occasionally necessary to work the machine in order to prevent it becoming useless and corroded with mud and chalk." Mr. Tylden Wright—one of the most able mining

engineers in this country—considers "that no more work has been done since the 5th July than was absolutely necessary, having regard to the conditions imposed by the order of the Court of that day."

It will be the opinion of impartial persons that the Submarine Tunnel Company have scored distinctly and heavily in this matter. An acute observer remarked that there was a good deal of human nature about men and women, and one of the happiest phases of this is its distinct sympathy with the oppressed. The Tunnel Company at this moment certainly appears to be the victim of official oppression, and bears its calamities with a dignity born less, we imagine, of resignation than of resolution. Recent events have tended much to influence popular opinion in its favour, and if Sir Edward Watkin and his friends keep "pegging away" as they have done hitherto, their honesty of purpose must sooner or later overcome an opposition which, though sometimes straightforward, is always unreasoning and impolitic, and often rancorous and envious to boot.

(*To be continued.*)

RAILWAY SIGNALLING.

LEVEL CROSSING GATES.

(*Continued from page* 213.

PLATES CLXVIII. and CXIX illustrate the arrangement and construction of level crossing gates and apparatus for safety operating the same, as employed by the Great Western Railway Company.

More attention is directed to some of the details of construction, as the method of working and locking the gates is similar to those already described.

When the crossing is at an angle other than 90° as shewn in the diagram at Fig. 268, Plate CLXVIII., the toothed gearing arranged at the heel of the gates are not all of the same radius, as before explained in other arrangements of similar apparatus.

Thus, assume the angle of crossing to be as upon the diagram, *i.e.*, obtuse angles 110 and acute angles 70°—then taking 9 inch toothed quadrants or arcs to be the dimensions of those to be fixed at *A A* or the obtuse angles, then $\frac{9'' \times 110^\circ}{70^\circ} = 14\frac{1}{8}''$ (about) would be the radius of the gear to be fitted at *B B* or the acute angles, in order to effect the simultaneous opening and closing of the gates. When the crossing is at a very acute angle, as represented by diagram Fig. 269, the gates at at *A A* require to be made short enough to swing clear of each other at *C*. The gates *B B* are consequently made larger than those at *A A*.

The distances between *A B* and *B A* must always be equal, the distances being measured from the centres of the toothed gearing on the heels of the gates.

At Fig. 270 of the drawings is given a diagrammatic Key Plan of the system. In the centre of the diagram will be noticed the three way double cranks for simultaneously operating the ordinary gate stops.

The four gates controlling the traffic at the crossing are placed between the posts or points marked *A*, *B*, *C* and *D*, while the small wicket-gates (for foot passengers only) are represented at *E* and *F*.

The connections for working the stops are formed of hollow rods or tubing $1\frac{1}{4}$ in. diameter, while those for operating the gates are solid and of about $1\frac{3}{8}$ in. diameter.

The quadrants or semi-circular gearing *a*, *b*, *c*, *d*, represent the toothed wheels before referred to, which are attached to the heels of the gates and operated by racks, all of which parts are illustrated in detail in later Figures of the drawings.

Figs. 271 to 276 represent jointly, an Elevation, Sections and Plans of the gateposts, with shoes, boxes, and gear in connection therewith, while Figs. 277, 278 shew an Elevation and Plan of the gates themselves. At Figs. 279 to 282 Plate CLXIX., are shewn various views of the capstan apparatus for working the gate stops, a similar arrangement of apparatus being (if desired) employed for actuating the gates. It simply consists of a common hand wheel *I* fixed on a shaft or spindle for operating the mitre gearing *K*, by which the necessary working motion is imparted to the shaft *J*. At Figs. 283, 284 of the drawings are shewn views of the small wicket gates and the apparatus in connection therewith, while Figs. 285 to 291 represent detail views of the hinges, hangers and shoes, &c., employed with the gates.

Referring to the Key Plan Fig. 270, it will be observed that the quadrants, cranks and gates, &c., are shewn at half throw, in which position the centre line of the quadrants must be at right angles with the racks. In their normal position the gates are shut across or against the public road, in which case the large stops are up and the small ones down.

The arrows upon the drawing indicate the direction in which the rods will move to close the gates against the railway, and

thus reverse the position of the stops. Usually about three levers and a capstan are employed to work this combined arrangement of apparatus.

The wicket gates *L*. Figs. 283, 284, fall into the position shewn, by virtue of the manner of mounting, and can be held there by the slack chain being drawn up, *i.e.*, the bottom hinge being fixed out of centre on the tubular post *T*, the gate always tends to close in the one direction. The total height of the wicket gates is about four feet. The gate posts are commonly formed of cast iron as shown at *P* Fig. 273, and are mounted in footstep bearings as at h^1. A box casing or suitable covering *g* is usually provided for protecting the toothed gearing for operating the gates, &c. The lengths of level crossing gates necessarily vary according to circumstances as above specified, but the standard length of gates at right angle crossings may be set about 14 feet, with a height of 5 feet. Each set of gates require two sets of stops—right and left handed—so as to effectually secure the gates in position.

The London and North Western Railway Company lock their level crossing gates at the heels by means of bolts passing into quadrant plates fixed thereon, and by a catch at the head which can only be withdrawn from the signal cabin. Both the bolts and the catches are worked by levers in the frame, which are suitably interlocked with the point and signals as previously described in our last issue.

The Midland Railway Company connect their crossing gates together by means of cranks and rods passing beneath the rails and communicating by a suitable connection with the nearest signal cabin, where the stops and gates are worked and controlled by levers interlocked in the usual way.

(*To be continued.*)

PARALLEL RODS OF LOCOMOTIVES.*

"SIDE rods have very commonly been considered one of the necessary evils in locomotive construction since the time when the earliest engineers discovered that the tractive force of one pair of wheels was not sufficient to haul heavy trains.

"The duty of a side rod is to transmit a rotary motion from the main driving axle to other parallel axles: to do this it must be stiff enough to transmit a thrust along its length without buckling. At high speeds it must be sufficiently strong to resist its own momentum; it must also have ends forming good bearing surfaces.

"There are many rods still running of a circular section throughout. These are cheap of manufacture, but being of the same rigidity, both vertically and horizontally, they are disproportioned. This was improved upon by making rods of elliptical section, but this was too expensive for a finished rod. A favourite way with some builders of heavy freight engines is to make their rods thick as well as deep rectangular bars. This is when the engine is not expected to run fast. Passing from this we find the ordinary proportion of rod to be about $1\frac{1}{2}$ in. by 4 in.; and we have on a great many railroads a rod with the middle section of about $1\frac{1}{4}$ in. multiplied by 5 in., that is, four times as deep as broad.

"Several attempts have been made of late years to find a lighter section of rod which will at the same time be stiff and cheap. In Germany, and also in this country, an I-beam section of rod has been used. The finished section of this rod will be found to be lighter than the ordinary rectangular section, the strength being mainly in the top and bottom flanges; and this section leads to a rod which is worthy of more consideration than it has hitherto received, simply two round bars of iron connected at the ends by brass castings. These rods have been used on switch engines, and have given satisfaction. There is a curious divergence of practice with regard to the section of rod throughout its length. Uniformity is the usual rule, but a large number of rods increase in depth toward the centre, in some cases as much as 1 in. One rod thickens in breadth toward the centre $\frac{1}{4}$ in., this being done by planing the rod while in a bent condition; while another excellent rod is thinned out in the middle from 1^7 in. at the ends to $1\frac{1}{4}$ in., while at the same time its depth is increased from $4\frac{1}{4}$ in. to 5 in., thus lessening the section from 8 square inches in the ends to $6\frac{1}{4}$ square inches in the middle, and at the same time keeping the vertical strength the same throughout. This rod is made of steel.

"A heavy side rod is such an impediment to an engine's rapid progress that the lighter it can be made the better. A very heavy rod, brought to our notice, weighed 314 lbs. Other weights of manufacturers' standard rods are 302 lbs. and 320 lbs. On the other hand, another rod, though but 9 in. shorter, weighs only 170 lbs., and is used for very fast traffic. Between these we have a great variety of weights. The rods of I-beam section are lighter than those of rectangular for equal strength; but a proper proportion of web to flange has not yet been reached in practice.

"With regard to rod ends there are three different systems. One type is that of a strap holding the brasses and secured to the rod by two or three bolts, and pierced by a cotter to take up wear. Another method is to forge the rod ends solid, and to form a wearing surface by inserting either ordinary brasses and cotter or a solid bush made of

* Paper read by Mr. Howard Fry before the Convention of Master Mechanics in America.

brass or white metal. The objections to the former are the great mass of metal required to firmly bolt the strap to the rod, and secondly, the weakening of the strap by piercing it with bolts and square cotter holes, and thirdly the liability of cotters to come loose.

"The disadvantages, on the other hand, put forward against solid ends, are that the wearing surfaces are not adjustable. As there is much to say on each of these methods, we will first consider the strap end.

"All rods with a strap require a large mass of metal for the strap bolts to pass through, as well as room for a cotter. This has been ingeniously modified in one instance, by placing the cotter between the two bolts, which necessitates, however, slotted bolt-holes in the rod end. A more direct way of tightening the end is to cut a large hole in the useless mass of metal.

"A still further step in the lightening of rod ends was taken by substituting solid bushes for adjustable brasses; and this method, so light, so secure, and so exact in its centres, is coming into general use. The rod end, which is generally of one piece with the rod, and of steel, is bored out in a boring mill, the last tool used being a reamer of standard size, and a bush is pressed into this hole by hydraulic or other means, the pressure used being about 35 tons, and is then secured, either by a taper pin passing through the joint, or by a key cast on the bush, the latter being riveted over when in its place. These bushes, when made of white metal, are cast in iron chills and need no machine work until after they are pressed into the rod, when they are bored out under a mill with tools a standard distance apart. With rods of this description it is easy to avoid getting brasses too tight or out of centre, and if one rod fails the rod on any other engine can be substituted for it.

"Some engineers in Europe have fitted their brasses into ball joints in order to give the wheels more lateral freedom, but the extra expense and double wearing surface can scarcely compensate for the very small advantage claimed. The rods of a very heavy 8-wheeled coupled engine on the Paris, Lyons, and Mediterranean Railway are equipped with these ball joints. All the wheels are flanged, and in order to get the engine to traverse curves of 580 feet radius, 1 inch side play in each direction is allowed in the leading and trailing axle boxes, and spherical or ball bearings in the side rods were necessary to allow this. There were 90 of these engines in successful use in 1880, with cylinders 21½ inches in diameter, 26-inch stroke, climbing grades of 1 in 33, and were first adopted in 1869.

"There is a tendency among some engineers to lessen the strokes of the side rod, which, however, can of course only be done on inside cylinder engines. As one instance of this a 7-ft. diameter 4-wheel coupled passenger engine, recently designed, with 19-in. by 26-in. cylinders, has a coupling-rod throw of only 18 in.

"The breadth of bearing for side rods is an important item in their length of service, and it is unfortunate that about 3½ in. seems the greatest breadth obtainable for outside cylinder engines.

"Iron is still generally used for side rods, although steel is rapidly coming into favour; but we have no data to show that the weight of rod has been correspondingly reduced. Where steel has been adopted a better section has generally also been used, which enables the rod to be lightened.

"Of the various mixtures of bearing metal each has its advocates; but phosphor bronze has been so successful that most bushes for solid-end rods and many sectional brasses are now made of it.

"White metal bushes are very cheap, owing to the small amount of machine work on them; but they sometimes work loose, which is probably due to the continued knockings which must more or less alter their shape. A good mixture for such bushes is, tin 16, antimony 2, copper 1.

"The cheapest rod is still the old strap rod, partly owing, no doubt, to the fact that what has always been made is easiest made. That the next cheapest is the solid bushed end, although with fluted sides, which is, as we have seen, the best rod where standard lengths can be maintained, and which bids fair, with a little practice, to be as cheap a rod to manufacture as the common strap-ended one; and lastly, that the solid-end, with brasses and cotter, is the most expensive.

"A great deal might be said on the time spent on finishing off rods. An engine is supposed by many people to be handsome when its parts are polished and its colours brilliant, and to accomplish this much valuable time has been spent and acres of emery cloth used. It is now more easily done by means of emery wheels, and some rods are allowed to go out straight from the grindstone and be painted. One of the largest railroads in England does not permit the rods to be touched after they come from the planer, but considers that a rod looks best when it shows least sign of laborious work. For a similar reason much of the bevelling of edges has been discontinued, especially in busy times, when it is necessary to get out work quickly."

PASSENGER LOCOMOTIVES AND HIGH SPEEDS.

WE are indebted to a correspondent of the *National Car Builder* of New York for some memoranda on the above subject. If twelve or fifteen cars are to constitute the future passenger train, and the speed is to be sixty miles an hour, a radical change must be made in the design and construction of passenger locomotives. Several new engines of this class have been built which run at this rate of speed, but it does not appear that they have taken as heavy trains at such speed as the average trains that are now hauled on many roads at the rate of 30 or 35 miles an hour. Many master mechanics are of the opinion that if 60 miles per hour with 10 or 15 coaches is demanded by the travelling public, a slight increase in the present sizes of the cylinders and boilers now in use is all that is necessary to meet the demand. An examination of the difficulties which lie in the way, however, will show that merely increasing the proportions of the present type of engines will not be sufficient. It is a mechanical truth that the resistance of a moving body increases the square of the speed; or in other words, doubling the speed of a moving body requires, not twice, but four times the power. To illustrate: If a balance wheel require a constant exertion of 10 pounds to keep it at a speed of 100 turns per minute, and it is desired to increase the speed to 200 turns per minute, it requires 4 + 10 or 40 pounds to accomplish it.

Applying this to the locomotive, and assuming the average speed now to be 30 miles an hour, the cylinders must be capable of giving off four times the power they now do, as the square of 30 is 900, and the square of 60 is 3,600, and this divided by 900 equals 4. Four times the quantity of steam must be generated (if the link motion is used), and to accomplish this the grate must be increased proportionally, unless by means of a stronger blast a greater quantity of fuel is burned per square foot than at present, and this is not desirable. Different authorities give different ratios of value of a square foot of heating surface in the fire-box as compared with the flues, but all agree that the fire-box is by far the most valuable source from which to generate steam. A larger fire-box would therefore be one of the changes necessary to be made to meet the new conditions. With the ordinary engine this could only be done by lengthening it; and owing to the excessive length and weight of side rods, which would then be necessary, high speed would be out of the question; and the fire-box is already as wide as the frames will admit.

The Wootten fire-box spreads over the top of the wheels, which must be made smaller in diameter to keep the centre of gravity of the engine low enough, and, it is claimed, the boilers are difficult to keep tight at the fire-box end. It should, therefore, appear that a pair of driving wheels back of the fire-box is out of the question. If, now, two pairs of drivers were placed under the cylinder part of the boiler, with a single pair of truck wheels ahead of these, and another pair back of the fire-box, and both arranged to distribute part of the weight coming on them upon the driving wheels, the fire-box might be made of a width equal to a passenger coach, and of any length desirable, and thus get in as large a fire-box as is necessary. It is obvious that a more economical use of steam must be made than is possible with the link motion. The success of Webb's compound engine, as well as those in use for several years past on French roads, would give much to be hoped for from the introduction of the compound principle, as it is claimed that the coal consumption was reduced from 30 pounds per mile to 22 pounds.

Many eminent master mechanics prefer the link to the Joy gear, on account of the increased lead which the link gives, as it is hooked back, and which the Joy gear does not; but it does not appear that this increase of lead is of any real advantage, providing the compression is properly arranged, and sufficient lead given, say one-eighth, to insure a prompt admission on the centre. With the link motion the expansion of steam is very limited, owing to the early exhaust. If a link-motion engine is hooked up to 6 inches, and the stroke be 24 inches, as the exhaust opens soon after the piston has travelled half its stroke, it appears that little over two expansions are gained and the steam is thus liberated from the cylinder, with a reduction of but one-half its pressure. If we suppose the steam to enter the cylinder at 100 pounds pressure, and to escape at 40 pounds, it is clear that the work stored up in the expansion of the steam from 40 down to a lower pressure, is thrown away. The compound engine accomplishes this by exhausting this 40 pounds into another cylinder instead of into the air, where it is again expanded, and the work represented by this expansion transferred to useful effect in propelling the load. It might be claimed that this extra expansion would be detrimental by weakening the effects of the exhaust, but it must be remembered that, as this expansion results in a less demand of steam from the boiler, the strength of the exhaust can be diminished with a further beneficial effect of lightening the wear and tear of the boiler and the cutting action of the cinders on the fire-box and flues. In the ordinary link-motion engine, where but $2\frac{1}{2}$ expansions are obtained on an average, it is impossible to hope for anything better from this device, in comparison with the compound engine, where probably 6 to

8 expansions are gained, and by the substitution of an independent cut-off to the compound engine 17 or 18 expansions might be gained, although the effects of the exhaust might then be too weak. From seven to eight expansions, or more, might be gained in a cylinder if an independent cut-off valve were substituted for the link-motion, although the number of expansions in a single cylinder would be limited by other conditions than the capabilities of the cut-off gear.

It appears settled that high speeds with heavy loads cannot be attained and maintained if the link motion is to be used, owing to its wasteful use of steam, and to the limited amount of power it developes when cutting off close. Cutting off at one-fourth the link will require an expenditure of water per horse-power of from 30 to 35 pounds. Any good automatic cut-off engine using the independent cut-off principle will perform the same labour on from 22 to 25 pounds of water per hour. Several years since the writer was employed by a road which was using on many of its engines the independent cut-off. As these engines were rebuilt the link was substituted for the independent cut-off. With the link they were never as smart nor as economical, and it was necessary on all of them to reduce the exhaust nozzles, thus proving that a greater quantity of steam was necessary.

THE EAMES' DUPLEX AUTOMATIC VACUUM BRAKE.

IN our July and August numbers we described and illustrated this Brake, of which we now give the couplings on Plate CLXVII. Figs. 1 to 5 are various views of the Plain Brake Pipe coupling, and Figs. 6, 7 and 8 represent the Automatic Pipe Coupling.

Both these couplings are so made that though air-tight when fixed, yet they will pull asunder without further manipulation being required other than the pull. So that in the case of a train parting, where these brakes are in use, the couplings will come asunder, instead of the hose breaking.

As explained in our previous numbers, to apply the brakes, whether automatically or otherwise, a vacuum must be instituted in the Plain Brake Pipe, and supposing the Automatic Brake to be called into requisition, air must be admitted into the Automatic Pipe.

So it is to be observed with these couplings, that on their parting, either by intention or by accident, the couplings of the Plain Brake Pipe will be closed by the falling of a circular disc over the aperture, and thus prevent the influx of air, while the other coupling remains open with free access for the air to destroy the vacuum. Thus the necessary conditions for the application of the brakes would be automatically fulfilled by any portion of the train breaking away.

Referring to the drawings of the Plain Brake coupling, in which the lettering is the same for all views, Fig. 1 is an Elevation of one coupling showing it closed, and Fig. 2 an End View. Fig. 3 is an Elevation, Fig. 4 a Plan, and Fig. 5 a Sectional Elevation of the couplings fixed together in working order. *E* are bearings with a pin *b* running through them, on which is pivotted a small lever *K*, with a disc or cap *c* at one end, and a thumb plate *a* at its other end. The disc end of the lever, when the couplings are not joined, is, by the action of a spiral spring *f*, brought down on to the aperture, where an india rubber packing ring *d* keeps it air-tight. Pressure of the thumb on the end *a* will bring *c* up. On each fellow coupling, which it will be noticed are made exactly alike, a tongue *g* projects, which on the parts being brought together, runs in between the bearings *E* of the other. At the root of this tongue is a cross groove *i*, into which fits a corresponding projection *h* on the lever *K*, forced down by the action of the spring *f*. The two parts are thus clasped firmly together above and below, and an air-tight joint secured by virtue of the india-rubber rings at *d*, while at the same time the parts may be pulled asunder by a less force than required to break the hose.

In the Automatic couplings, of which Fig. 6 represents a Sectional Elevation of one, and Fig. 7 an Elevation of two joined together, and Fig. 8 an End View of one, the projections *r* and *s* admit of the two parts being jambed up and sprung together as shown in Fig. 7, and firmly united with a joint air-tight by means of the india-rubber packing *t*, while they may yet be pulled asunder by a force less than sufficient to break the hose, as in the case of the Plain Brake coupling.

Fig. 9 is the Vacuum Gauge employed, which has a plug valve attached as shown at *W*, by which air may be admitted to the Pipes if necessary.

PROGRESS OF ENGLISH RAILWAYS.

IN the report, presented to the Board of Trade by Mr. Henry G. Calcraft and Mr. R. Giffen, recently published as a Parliamentary paper, we note the following paragraph:—"In our report a year ago on the capital, traffic, working expenditure, net earnings, and dividends of the railways of the United Kingdom, we had to call attention mainly to the remarkable progress of these undertakings in earnings and profits during the year 1880, as compared with the previous year 1879, which had been one of considerable depression. We pointed out that while 1879 had been a year of depression, yet even in that year there had been great progress in many respects as compared with a period ten years before; that the depression was only marked on comparison with an intermediate period of prosperity; and that in 1880 the depression had been almost wholly recovered from, the amount of traffic and profits earned being greater than in any previous year, and the rate per cent. of net earnings on the whole capital, and the rate of dividend paid on the ordinary capital, being about as high as they had ever been, although the amounts in all cases had increased. The tables for the year 1881 exhibit how far the improvement of the year 1880 has continued. According to former experience, it would not be unreasonable to anticipate a continuance of improvement for several years, after a re-action from circumstances of great depression had set in, but even if the anticipation is found to be fulfilled the exact nature and extent of the improvement could only be ascertained by a careful survey of the facts.

The mileage of 1881 shows an average of 18,175 as against 17,933 miles in 1880, an increase of 242 miles. The working expenditure was in 1881, £34,900,000, and in 1880, £33,601,124, an increase of £1,298,876.

It is most evident that the improvement of 1880 has been maintained in 1881. The receipts from traffic of all kinds show an increase of 2.5 per cent., and although the working expenditure has increased at a still greater ratio, viz., 3.9 per cent., still this increase is on a smaller amount than the increase of traffic, and the latter is not entirely swallowed up; there remains an increase of net earnings which is no doubt small, being only £364,000, in amount, and in the proportion of 1.1 per cent., but which is still an increase and on the right side of the account. The mileage has again increased at the rate of 1.3 per cent., and although the increase of capital is rather greater, being at the rate of 2.4 as compared with 1.6 per cent. last year, still this increase is partly nominal, being due to conversion operations, and it cannot be said that the disparity between capital and mileage is greatly increasing. The capital expended per mile open is £41,019, as compared with £40,613, in 1880, an increase of 1 per cent. The apparent amount of increase of gross traffic is £1,663,000, of which £492,000, is from passengers, £1,039,000 from goods and £132,000 from miscellaneous sources; and the rate of increase as already stated is 2.5 per cent. The apparent increase of working expenditure is £1,299,000, and 3.9 per cent., while the increase of net earnings is apparently £364,000, and 1.1 per cent. This last result shows a comparatively stationary position as regards profits earned and dividends on ordinary capital. While capital has increased 2 per cent. the net earnings and amount of dividend paid have increased 1 per cent.; so that the reduction in the rates of net earnings and dividends is quite inappreciable.

The reduction in these rates would appear to be from 4.38 to 4.33 per cent. as far as the percentage of net earnings on total capital is concerned, and from 4.72 to 4.66 per cent. as far as the dividend paid on the ordinary capital is concerned. In other words, the improvement of 1880, as regards traffic, has been fully maintained in 1881, and more than maintained; but as regards net earnings and dividends, while the amounts have increased, the rates on the capital have fractionally diminished. The rate of dividend on the ordinary capital is higher than in any year since 1873, with the exception of 1875 and 1880, when it was fractionally higher.

The amount of the increase of capital, £17,211,000, though larger than in 1880, is still under the average of a long period past, especially when allowance is made for the fact that part of this £17,211,000, is due to conversion operations.

The proportions of the different kinds of paid-up capital have remained the same in 1881 as in 1880. We have thus no additional remarks to make on the opposite tendencies which we noticed a year ago as existing among Railway Companies in regard to the form which they give to new issues of capital. It still remains true that when we take a number of years into account the proportion of ordinary capital tends, on the whole, to diminish, but it is also true that of late years the leading Companies have shown a disposition to add to their ordinary capital, so as to maintain its proportion to the rest.

The apparent rate of increase of passenger receipts is 1.8 per cent., and of goods 2.9 per cent. The increases in the previous year having been 5 and 6.8 per cent. respectively, the farther improvement shown would seem to be very satisfactory. It will be recollected that early in 1881 all kinds of railway traffic were impeded by the severity of the weather, and business, it was

generally believed, received a temporary check, which lasted into the summer. Still both passenger and goods traffic, for the whole year, appreciably increased above the large totals of 1880.

The distribution of the increase from passengers again illustrates the point to which we have frequently drawn attention in previous reports, viz., the tendency of the third-class traffic of railways to increase at the expense of all the others.

The increase of periodical tickets may perhaps be considered to compensate a little the diminution of first and second class traffic, but it can only do so very partially. The broad fact remains that in 1881, as for a good many previous years, the third-class traffic has increased greatly, while first and second-class traffic has diminished.

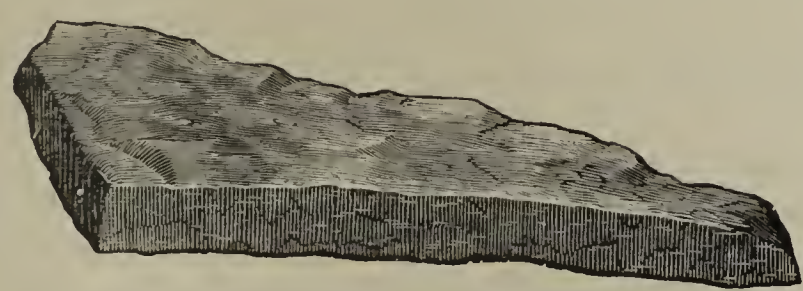
As was the case in 1880, so also in 1881, there is a decrease of the receipt per train mile as compared with the previous year —not large, but sufficient to show that the increase of income is obtained from a larger and not from a smaller service to the public than formerly. The receipt per train mile from passengers is 51.57d. as compared with 52.65d. in 1880, 53.35d. in 1879, and still higher figures in previous years. The receipt per train mile from goods is 72·76d. as compared with 73.66 in 1880, 73.85d. in 1879, and still higher figures in previous years.

We may close this report in almost the same language which we used a year ago respecting 1880. The year 1881 has, on the whole, been a prosperous year for Railway Companies. There has been a large increase of traffic, while working expenses have remained moderate, and the addition to net earnings has been so great as to make the return to those interested larger in amount than in any previous year, and at almost as high a rate as in the most prosperous year which railway shareholders have yet enjoyed. In particular the rate of dividend on the ordinary capital has been higher than in any year since 1873, except 1875 and 1880, notwithstanding an increase of capital in the interval. There is nothing to diminish the satisfaction with which the figures must be viewed as showing the steady growth of the business and prosperity of the country, the facts as to the increase of goods traffic and third-class passenger traffic which we have stated being in every way remarkable.

BOILER FLUID.

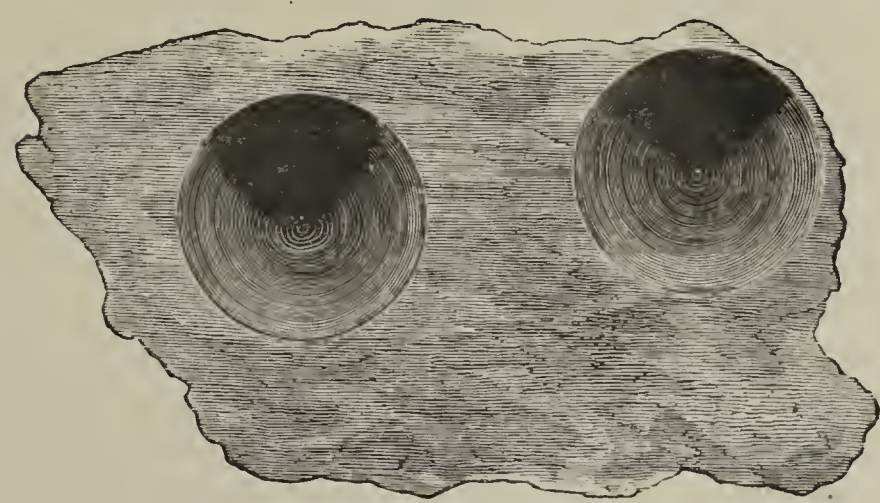
WE have received some particulars of the "Oldham" boiler fluid for the prevention of incrustation and corrosion. The manufacturers are Messrs. Eckersley Brothers, of Lees Road, Oldham, and recent experiments have, according to the reports before us, quite justified the claim which they put forward as to the special merits of this fluid. The result of the trials seem to show that the fluid :—

Keeps new boilers internally clean; eradicates corrosion and incrustation in old boilers; will not allow mud to settle on the boiler plates; enables the steam to be "got up" more easily and quickly; requires less labour to "keep up" steam; causes less coal to be wasted; deodorises foul water;



Scale 1 inch thick at front edge, taken out of Boilers, Union Mills, Lees Road, Oldham.

is a smoke preventer; prevents the boiler plates oxidising after the incrustation and corrosion are removed; is practically the cheapest boiler fluid in the market; is quite free from solid matter; will cause no injury to the clacks, valves, boiler pipes, cylinders, or economiser pipes; destroys all organic matter, and holds it in solution; neutralises all detrimental mineral particles; can always be relied on as being uniform in quality, is guaranteed free from acids;



Scale off Rivets or Boltheads, taken out of Boilers, Union Mills, Lees Road, Oldham.

does not injure dyers' colours; is especially adapted for keeping stationary or locomotive engine feed pipes clean and open, and may be used to clean all kinds of dirty, greasy, rusty ironwork, paint, varnish, crockery, glass, marble, etc.

THE IRON AND STEEL INSTITUTE.

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ON the 19th ult. the Iron and Steel Institute autumn meeting was opened at the hall of the Austrian Society of Engineers and Architects, Echenbasse Strasse, Vienna.

Mr. I. LOWTHIAN BELL, F.R.S., a past president of the Institute presided.

The first paper read was one by Hofrath Ritter von Tunner of Leoben, on the Styrian iron trade. The paper of Mr. Tunner did not, as might have been expected, contain any figures indicative of the size of the Austrian iron industries, but dealt with the conditions under which the industry was followed, and the special circumstances that prevented the achievement of a high degree of development. Those special circumstances chiefly related to dear capital, high railway freights, the numerous festivals among the Roman Catholic workmen, and, above all, to the absence of mineral fuel, which compelled the ironmasters of Austria to use charcoal fuel almost exclusively. The learned Professor, however, pointed out that Styria could claim several metallurgical improvements and departures of high importance, and it had recently established its right to be regarded as fully alive to the march of events by adopting the Thomas-Gilchrist process at some of its most important works. The Austrian Alpine countries were the first to produce ferro-manganese direct from the blast furnace, and they were the first to adopt and improve the Bessemer process. The use of the Siemens furnace for puddling and welding was first tried in Styria; cast steel was also first produced from the Siemens furnace at Kaffenberg in Styria; and the Professor believed that the production of Bessemer metal by direct connexion with a Siemens furnace was first carried out at Neuberg, in Styria. Professor Tunner, it may be added, has long occupied a leading position in the metallurgical world, and is regarded throughout Europe, and, indeed, wherever iron is produced, as one of the chief authorities respecting that industry. For many years he acted as Professor of Metallurgy at the Royal Mining Academy at Leoben, which, after that at Fahlun, in Sweden, as he himself in his paper pointed out, was the first established for the special purpose that is now represented by the School of Mines in Jermyn-street, and to some extent by the science classes in South Kensington, and by the Ecole des Mines in Paris. His paper, therefore, it need hardly be said, was listened to with marked attention, and at its close the usual vote of thanks was awarded with extreme cordiality.

The next paper read was one by Professor Korpely, of Buda-Pesth, on the Hungarian iron industry. Accompanying this paper was an excellent map of Hungary, in which the ironworks and railways were distinctly marked. It showed that the country has in some districts a very large number of works, although mostly of very small dimensions, the total annual production of pig-iron being less than 200,000 tons per annum. The paper referred to the special conditions under which the iron industry of Hungary is being carried on, and more particularly to the fact that a great many works are finding the supply of charcoal giving out, and were now compelled to use the brown coal, or lignite, with which the country abounds.

The only paper of the day that provoked any discussion whatever was that prepared by the manager of the works at Teplitz, in Bohemia. To that country the process has been one of very great advantage, the only pig iron available without going a very long distance, containing a high proportion of phosphorus, and not being otherwise adapted for the manufacture of steel. The country also labours under the disadvantage of having no proximate coal supplies of mineral fuel, and hence the proprietors of the Teplitz works have made peculiar and exceptional arrangements for the utilization of their enormous brown coal deposits instead of the fuel usually employed in the steel manufacture. It appeared from the paper that the endeavours made in this direction had been attended with signal success, the whole of the steel manufactured at Teplitz being produced with brown coal, excepting only a very small quantity of coke used in heating the ladles, so that, instead of being compelled to import coke from Silesia, or some even more remote district, at a cost perhaps of 20s. to 30s. per ton, the works are in a position to use brown coal deposits in their own immediate neighbourhood, which are worked so cheaply that much of it is available at less than 1s. per ton. The thickness of the principal deposit varies from 10 to 30 metres and in some places there is a thickness of even 38 metres. The depth of the deposit never exceeds 200 metres, the average being about 100 metres, and in some places it is so near to the surface that it can be easily worked in the open. The Teplitz works require for the carrying out of the Thomas-Gilchrist process about 20 charges of six to six and a half tons daily, about 1,320 cubic metres of brown coal, and 1·6 cubic metres of coke, so that the quantity of coke required is only 0·1 per cent. of the total fuel employed. Brown coal, therefore, is used almost exclusively for the carrying out of the process.

THE INNER CIRCLE RAILWAY.

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ANOTHER length of the Metropolitan line, reaching from the Three Nuns, Aldgate, to Tower Hill, is opened; and there is now wanting but one more link to complete the encircling chain of underground railway communication for London. The distance accomplished by the newly opened length is no more than a quarter of a mile; but the permanent way is completed for seven or eight chains beyond its present termination, and much of the required property in the neighbourhood of Cannon Street is already purchased. The rapid construction of the line from Aldgate to the Tower, by Mr. T. A. Walker, the contractor for the Severn Tunnel, for the new street from London Bridge to Trinity Square, and for the completion of the inner circle of the Metropolitan Railway, has been one of the triumphs of modern engineering. Little more than a twelvemonth has been occupied with this task, the labour being expedited by crowding on all the men and horses that could find room to work in. Mr. John Bell, the general manager of the Metropolitan Railway; Mr. Seaton, the resident engineer; Mr. Wardhaugh, representing the contractor; and Mr. Tomlinson, the engineer to the company, conducted a party of gentlemen over the new length of line, which commences with a junction of the Metropolitan Railway at Aldgate Station, passing under the main thoroughfare of Aldgate High-street, through Chequer's Yard to the Minories. Thence the line passes under the Blackwall Railway, through the Crescent, and on to Trinity Square, Tower Hill, under the gardens of the square, terminating at the west side, near to the church of All-hallows, Barking. The railway is carried under High Street, Aldgate, by a bridge of 82 ft. span, constructed of heavy wrought-iron girders, and is sufficiently wide to admit of four lines and two platforms. The tunnel is 25 ft. wide, the arches of stock bricks, being in some places 3 ft. thick. In passing under the Blackwall Railway it was necessary to underpin the abutments of the arches, and great care had to be taken in this part of the work, as trains were passing over it constantly during its construction. The Tower of London Station, a temporary but well-arranged structure of wood, on the east side of Trinity Square, has platforms 300 ft. long and 12 ft. wide. The ventilation has been carefully attended to. On leaving Aldgate Station the train enters an open cutting seventy yards in length, after which comes the tunnel, which, at one portion, was illuminated by the Swan electric light. Then succeeds another piece of open, and a short passage through a covered way brings the train into the open station. The first sod of the extension was cut on September 5, 1881, by the late Lord Mayor (Alderman M'Arthur). For the first time in the history of underground railways the traffic of the streets was not stopped by the construction of this extension. No serious accident had occurred during the progress of the work, and none of the buildings on the way show any sign of damage. In the excavation some curious pieces of pottery, many being of the time of the Roman occupation, have been found, and these have been sent to the British Museum. A portion of old London wall, 8 ft. thick, had to be removed. It was built of Kentish rag-stone, levelled up with three courses of Roman tiles. Passing through the old ditch, many objects of interest were found, and many tons weight of bullocks' horns were removed. By means of the new length of line and the Tower Station, to which passengers may book, easy access is gained to the Tower of London, the docks, Mark-lane, Mincing-lane, Billingsgate, the Corn Market, and all the great centres of business in the City.

RAILWAY ACCIDENT IN HUNGARY.

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AN appalling railway accident, similar to the Tay Bridge disaster, occurred on the 24th ult., on the line connecting the occupied provinces with Hungary. At a small town called Esseg, on the confines of Sclavonia, the railroad crosses a wooden bridge over the river Drave, which has lately risen considerably above its normal level, inundating a great part of the country through which it flows. At Esseg it formed a rushing torrent, and it had reached 278 centimetres above flood-line. The bridge itself is a somewhat primitive wooden construction, reposing on piers of the same material. It has been used for railway traffic for the last twelve years, but was to be replaced by an iron structure next December. It must have been in bad condition, as it had long been predicted that sooner or later an accident must happen. The heavy current resulting from the flooded state of the river had drifted all kinds of *debris* against the bridge, which does not appear to have been provided with cutwaters. Hence the floating rubbish accumulated, and this was doubtless the main cause of the disaster. The passengers of the ill-fated train consisted almost exclusively of a part of the 15th Hussar Regiment, returning home on leave from Serajevo and Mostar. Just as the first part of it was crossing the sixth and seventh arches of the bridge the woodwork gave

way, and, accompanied by a loud crash, the engine, tender, two goods vans, and two passenger carriages were hurled into the swollen stream below. Some thirty men were drowned, the number of those who escaped being estimated at forty-nine. The engine driver and stoker managed to swim to shore, and although the breach measured sixty metres, the rest of the train remained on the bridge, the coupling chains having fortunately snapped asunder. Seventeen men were more or less seriously injured, but the officers who were in the end carriage do not appear to have been hurt. An engineer and his assistant, who happened to be on the bridge when the accident occurred, also escaped, the former by swimming ashore, and the latter by catching hold of a protruding plank as he fell. They were the only eye-witnesses of what occurred. Unfortunately their testimony, as it has hitherto reached us, is confined to the statement that the bridge sunk gradually, so that the unhappy victims must have had time to realize fully the terrible fate that awaited them. One of the carriages fell on a sandbank, and the roof is just visible above water. The other fell in the middle of the torrent, and was carried 300 metres down the river. It is hardly necessary to say that the news of this fresh disaster has caused profound consternation throughout the country. Although less serious in its consequences than the catastrophe at Segedin, the burning of the Ring theatre, or the floods in the Tyrol, it is of a particularly distressing character. The poor fellows who met with such an untimely end had, after three or four years' exile and hardship, obtained their well-earned discharge from the ranks, and were no doubt eagerly looking forward to meeting their friends again. Many of them had escaped death on the battlefield in Bosnia, and others had recovered from sickness that has lately been so prevalent among the troops in the occupied provinces.

A NATIONAL EXHIBITION OF IMPROVED RAILWAY COUPLINGS AND APPLIANCES.

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ON Tuesday next will be opened at the Volunteers' Drill Hall, Darlington, an Exhibition of great general and philanthropic interest, at which there will be exhibited every description of improved railway couplings and coupling appliances, electric communications in trains, fog signalling apparatus, signalling appliances, electrical inventions, working models of locomotives and other railway machinery. Experiments with couplings and couplers will be made in the yard adjoining the hall with full sized wagons, and medals, and certificates of merit will be awarded to successful competitors. The exhibition takes place under the approval of the Board of Trade, and is under the patronage of the Mayors of Darlington and Stockton-on-Tees, several members of Parliament, and an influential list of local gentlemen. The following extracts from the "Preliminary Notice" will explain the project:—

"The exhibition is promoted by the Amalgamated Society of Railway Servants, assisted by many patrons and friends, with the sole object of better protecting the lives and personal safety of railway servants engaged in the work of coupling and uncoupling railway vehicles. It is estimated that 14,000 men regularly engage in the work, and of this number the returns made by the Companies to the Board of Trade show 206 to have been killed, besides 1,614 personally injured, in the five years ending with 1880. The risk incurred arises mainly from the universal use of link or chain couplings, and the necessity, in the absence of appliances, of men placing themselves between the vehicles, and therefore passing over the rails in attaching or de taching wagons.

"The promoters desire to demonstrate (if it is, as they believe, possible to do so) that the use of improved couplings, or of appliances to be used in coupling and uncoupling operations, will materially reduce, if not absolutely remove, the constant risk of accident from the cause alluded to; and that the adoption of such improvements will be an economy of labour and of time, and, therefore, in the end profitable to the Railway Companies.

"The promoters are at least anxious that the Exhibition shall secure for the subject the due consideration which the preservation of human life and the prevention of suffering claim at the hands of all who direct the affairs of railways, or who use them.

"The Board of Trade have issued a certificate under 'The Protection of Inventions Act, 1870,' which protects unpatented inventions from infringement when on view at the Exhibition, and further promise to direct the attention of their Railway Inspecting Officers to the undertaking, and declare "that they (the Board) have every wish to encourage the examination and consideration of such appliances.'"

This is a simple programme which will commend itself to every one who is practically acquainted with the purposes to which the Exhibition is devoted, and would, we are sure, receive extended support from the outside public had their assistance been sought. It is very difficult to get at the recognized leaders of philanthropy on questions affecting individual interests, and an Exhibition of this kind is to a certain extent

necessarily brought out under local influence. In this case we are happy to notice that the influence is strong, and that the gentlemen who have given the sanction of their names are calculated in every way to secure the success of a most deserving enterprise. We are in no way depreciating the value of their support when we regret the absence of certain names which would have convinced the world of its national character. Lord Shaftesbury has made himself immortal as the friend of his toiling countrymen. The Baroness Burdett-Coutts is ever ready in the cause of humanity, and the Lord Mayor has given repeated evidence of his appreciation of the eleemosynary duties of his office. No doubt the promoters of this exhibition are justified in relying largely upon the support of the various branches of their own profession, but it would have been a graceful fact if some who are so generous to those "who toil not, neither do they spin," had made acquaintance with a project calculated to ameliorate the condition of a numerous class who run as many risks as seamen, firemen, or any others engaged in occupations of danger, but have never yet, so far as we are aware, been made the objects of material public sympathy. Accidents to railway servants have become too much a matter of course. Public opinion, its leaders and exponents, regard them with an accustomed eye. Accidents involving damage or death to passengers are chronicled with melodramatic emphasis, and inquired into with all the forces of the Board of Trade. But fatalities to railway subordinates seem to be recognized as all in the day's work, and the verdict of a coroner's jury, which nobody takes the trouble to read, is the sole requiem of the forty annual victims of this special Moloch. The gospel of self-help will not have been preached in vain if the results of the present exhibition, which is organized by those who represent the men themselves, shall convey to the public a knowledge of the dangers to which those who so loyally serve them are subjected, and the means by which they may possibly be obviated. A railway servant must not be regarded as responsible to his Company alone. Every traveller depends upon his efficiency and exactitude, and the travelling public, as well as the great railway companies, should take an interest in the conditions under which he performs his responsible and laborious work.

We are most happy, though in no way surprised to find that the appeal made to the Railway Companies has been generously responded to. The North Eastern, Manchester, Sheffield and Lincoln, and North British Companies have not only consented to send samples of all the various patterns of couplings in use on their respective lines, but will carry all exhibits to their destination at half the usual freight. By the kindness of the North Eastern Railway Company, a siding will be improvised in the entrance to the Drill Hall, on which wagons will be placed, coupling sticks, couplers, &c.; and full-sized couplings tested on these wagons. Further, a siding will be set apart for the purpose of experimenting with couplers, sticks, wagons, and improved couplings. Competitive trials with coupling poles will take place at the Gn. Sidings, Bank Top, on Thursday, 5th, at 2 p.m.

We very much regret that the catalogue is not yet sufficiently advanced to enable us to give a synopsis of the exhibits, but we have official assurance that they will comprise samples of all known inventions in this respect. The promoters have shown their wisdom in not confining themselves absolutely to couplings, but invite also models of "Railway Inventions and Improvements of General Interest" of other kinds. And we may venture to conclude by quoting the last paragraph of the prospectus—an appeal to which we, certainly, find no difficulty in responding:—

"In conclusion, the Amalgamated Society of Railway Servants earnestly appeal for the continued assistance of the Public, the Press, and the Companies in the effort to stay the march of death and mutilation which play havoc in the ranks of the working railway service, carrying suffering and sorrow into hundreds of humble homes. The Society seek no pecuniary gain by the Exhibition. On the contrary, they are incurring a great expense in furthering the cause of human safety, and trust to the generosity of the humane wealthy to assist them in bearing the burden undertaken."

MR. LIVESEY'S IRON PERMANENT WAY.

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AT a recent meeting of the French Society of Civil Engineers a communication was received from M. Seyrig on Mr. Livesey's Iron Permanent Way. The system consists in a bell of an oval form, either in metal or iron, the upper part of which has a flat face, and on this the rail rests. On the outer side the face has a rim against which the rail rests through the entire length of the rest. At the end are hooks covering the frog and preventing any rise. Inside this is a projection of the metalcovering a steel plate ribbed on the open side and striated on that next the rail. The inclination of the plate is made to fit like a metal wedge, and this is driven between the plate and the flat bottom of the rail, and serves the purpose of the ordinary wooden wedge. The wedge has slight lines corresponding to those of the plate, and when driven home by the hammer and the striated lines enter into those of the fixed part, it is evident that no loose-

ning can be effected by the vibration caused by the passage of the wheels, while a single blow of the hammer in the opposite direction will loosen the whole. Two similar bells form a girder and are joined together by a flat iron laid edgeways. Two different methods of union can be used. A single collar in a central indentation under the axis of the rail itself may be employed, or a curved gib which cannot be taken out when the rail is once laid. This arrangement, however, does not allow of the road being enlarged at certain points, as is generally done in curves. In lines of low speed and large curves this widening is often lost sight of, but with the metallic ties the widening can be made very simply by using a collar and gib placed on each side of the bell. These two pieces are of different sizes, and it is very easy to see that by putting the thinnest piece either inside or outside, and to one of the bells or both, we shall have three sizes of way, and these will be sufficient for ordinary lines. M. Seyrig stated that, in order to have lines that will be more theoretically perfect, it can be done by having ties perforated in a different way. He is of the opinion that rust is not what is to be feared for iron sleepers, as 30 or 40 years will not destroy such a bell with a thickness of eight or nine millimeters. The great point in a metallic way is to have the bed so solid that no vibration will loosen its ties. The least mobility between the parts entails the rapid destruction of the line, while constituting a permanent source of danger. The pieces should be also as few and as simple as possible. The bearing of the rail on the sleeper should be as lengthy as possible, and to this end the oval form has been selected. While diminishing the number of sleepers, it allows the resting points of the rail to be brought closer together. The form of a bell has a considerable advantage over that of the ordinary sleeper, as the surface of support is entirely concentrated on the resting point of the rail itself. It is not so in the case of the sleeper, as one-third of it, in the middle of the roadway, is badly placed, and if the ballasting is not well kept up, or if the tamping is too great, the road is likely to give a rolling motion. This often leads to the breaking of wooden sleepers. The use of bells makes this impossible, as the vertical position of the tie prevents any resistance beneath it. The weight of the bell must be calculated according to the rolling weight on the line. On ordinary ones it varies from 45 to 50 kilos (100 to 110 pounds). On narrow lines from 55 to 88 pounds will be sufficient. I broken stones are used for ballasting they should be smaller than usual. The calculations for such a road show only 13,649 francs per kilometer, as against 27,550 francs for the wooden sleepers. Wooden sleepers last only a short time in Algeria, and doubtless experiments will be made in this direction.

A RAPID SYSTEM OF LAYING TRACK.

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TRACK-LAYING is now in progress at three different points on the Chicago and Atlantic road. The system used is that invented and owned by Mr. George F. Harris, of New York, the contractor for laying the track. One apparatus and gang of men is now at work on the Chicago end of the line, laying track south-easterly from State Line. By invitation of Mr. Harris a representative of the American *Railway Review* visited the scene of operation, and found the track well laid and ballasting progressing slowly. The indications are that the road will be exceptionally well built. The rails are Edgar Thomson steel and are fastened by the Standard rail joint.

Track-laying is going on at the rate of 5,400 feet a day, and there was considerable curiosity in the minds of the guests to witness the *modus operandi*. At a point about three miles beyond Kouts Station (crossing of the Pan-Handle Road) the gang of track-layers were found.

The apparatus employed is remarkably simple. A tramway track with a gauge of about eight feet is laid on top of the whole train of flat cars. The connection between cars is made by short lengths of the rail held securely in place, but with play enough not to interfere with the motion of the cars. The ingenious joint fastening permits the easy removal of these connecting rails after the train is unloaded. From the end or "Pioneer" car of the train there projects an adjustable frame-work upon which the tramway track extends. This frame-work is easily taken off when the train is unloaded and placed upon the "Pioneer" car of the next train which comes up. The tramway is for the use of an automatic dump-car, which carries the ties from the rear cars of the train to the front. Along the central longitudinal line of the top of the cars for carrying rails are placed rollers—five to each car. The rails are loaded on the forward cars and the ties on the rear cars of the train, nearest the engine. The rails are loaded longitudinally between the rolls and the tram rails. The ties of the tramway prevent the rails from coming closely in contact with the floor of the cars, and in the space between are placed the joint fastenings.

The operation is as follows: Let us suppose that the train loaded with rails and ties is in position, with the forward end of the pioneer car just at the end of the track. Upon the train are two or more men for handling ties, and two for handling rails. Upon the grade forward is a gang of men for putting the ties and rails in place, spiking, bolting, &c. The men in charge of the tram car load it with ties enough for two rail lengths, and push it rapidly along the tramway to the

end of the projecting track; there the car is suddenly stopped by cross blocks, and the load of ties is dumped crosswise upon the grade. The track layers place the tiles in position and put upon them three easily-handled conical trestles, with roller tops. Meanwhile the tram car has been taken back for reloading. The men in charge of rails on the train catch the rails through the bolt holes by means of hooks and draw them rapidly along on the rollers two at a time. When on the pioneer car, they put the pair of angle bars upon the forward end of each rail, securing them loosely and hastily by one bolt only. They then guide the rails along the rollers, off from the cars and on to the rollers of the trestle. The track-layers grasp the rails, lift them up and drop them into place on the ties. Two more rails are run out and laid in the same manner on the ties. The joints are bolted and each rail spiked to three or four ties. The train then moves up to the end of the track, and the same operation is repeated. A little practice gives the men great facility, and the work moves with the greatest rapidity and precision. Other gangs of men follow the train and finish the spiking, bolting, and lining up. So smoothly is the whole thing done, that a force of about 55 men is here completing over a mile of track-laying each day.

The advantages of laying track by some such process as this are clear, and are undeniably great. The use of teams is entirely done away with, and the track is laid easily through swamps, over trestles, through cuts and over embankments. The work of lifting and carrying ties and rails is reduced to a minimum. The result is vastly increased speed and decreased cost to the contractor. The advantage to the railway company, besides the speed which is often very important, is that the grade is left in as good condition as before the track is laid. It is not cut up by teaming and by carrying materials up and down the sides of embankments and cuts. The work is performed in so small a space that it can easily be carried on by means of artificial light at night.

OFFICIAL REPORTS ON RECENT ACCIDENTS.

Major-General Hutchinson has reported the result of his inquiry into the circumstances connected with a slight collision which occurred on the 1st June last close to Thirsk station, at the junction of the line from Leeds to Thirsk with the main line from York to Newcastle. This collision at Thirsk junction, between a special passenger train from York and the 3.45 p.m. passenger from Leeds, was entirely due to the carelessness of the driver of the Leeds train in starting from the ticket platform with the junction signal against him. He had no doubt made sure that the signal would be lowered after he had whistled, and accordingly started in anticipation of this; but just after starting, becoming aware that a train was approaching the junction on the main down line, and having command of a quickly-acting brake, he was fortunately able to stop after he had moved forward about 20 yards, and the collision then took place between the engines, that of the special train (the driver of which had seen what was imminent, and had had time to reduce his speed from 15 miles to 3 or 4 miles an hour) having had its four front wheels thrown off the rails. The junction signalman appears to have acted in compliance with the block telegraph regulations, and not to have accepted the signal for the special train until the Leeds train had come to a stand at the ticket platform. Considering, however, that in the ordinary course of working the Leeds train would have been permitted to proceed into the station as soon as the tickets had been collected, it would only have been wise in him to have attracted the driver's attention to the fact that a train on the main line was being allowed to precede him. An improvement in the nature of the junction down-signals for the Leeds line is certainly desirable, considering that almost all down passenger trains stop at the ticket platform. A rear home-signal to admit trains to the ticket platform and to protect them when standing there, should be provided; and the present home-signal, which would then become a starting-signal, should be placed in a position where it could be better seen than at present by the driver of an engine standing at the north end of the ticket platform. The advantage of a *quickly-acting* continuous brake on the Leeds train was very conspicuous in the present instance. Without it the collision would have probably taken place between the engine of the special train and some of the carriages of the Leeds train, and have probably been attended with far more serious results than was happily the case.

Major-General Hutchinson has also reported the result of his inquiry into the circumstances connected with the collision which occurred on the 14th July last, at Denburn junction, Aberdeen, on the Caledonian Railway. This slight collision between a Caledonian Company's engine and tender (running tender first) and the rear of a Great North of Scotland Company's passenger train from Ballater to Aberdeen while the latter was standing at Denburn junction down home-signal waiting for it to be lowered, was entirely due to the driver of the unattached engine not keeping a proper look out ahead as he was approaching Denburn junction. He

states that he had seen the passenger train pass the Ferry Hill engine shed towards Aberdeen, that he followed it after a short interval, saw (by leaning over the side of the tender, which was heaped up with coals), when about a quarter of a mile off, that it had been stopped at the junction home signal, and immediately afterwards noticed the home-signal taken off; that upon this he jumped to the conclusion that the signal had been lowered for the passenger train (whereas it had been actually taken off for another unattached engine in front of the passenger train), and that the passenger train had proceeded into the station; that he was unaware that the train was still standing at the home signal until he heard the guard shout out, when his tender was only about six yards from the van of the passenger train and his speed about six miles an hour; and that he had time to do nothing before the collision, which was so slight that it did not knock the fireman (whom it took quite unawares) off the front buffer-beam of the engine, where he had been standing for some time fastening the smoke-box door. Had the fireman been in his proper place on the foot-plate of the engine, instead of in the rear fastening the smoke-box door, which he ought to have done before leaving the Ferry Hill shed, it is possible he would have seen the train in time to have warned his driver to stop, and he, therefore, as well as the driver, is deserving of censure. The Great North of Scotland Company's servants with the Ballater train do not appear to be to blame. The guard was, I think, quite justified in assuming that his train, standing with its van at least (there is some doubt as to its exact position) 245 yards inside the down distant signal, and with its engine near the home-signal, on a perfectly clear morning, was properly protected. Owing to the constant passage of engines between Ferry Hill junction engine sheds and Aberdeen station it is stated to be an impossibility to work the absolute block system between Ferry Hill and Denburn junctions. This is very likely the case, but at any rate it might be possible to block both before and behind passenger trains; and I should recommend this being done. It seems also desirable to put up a down rear signal at Denburn junction to protect trains standing at the ticket platform, and to move the down distant-signal further south. The mode of working the Deeside trains between Aberdeen station and the Deeside (single) line appears capable of being improved. As it is, no Deeside train is allowed to leave Aberdeen station for Ferry Hill junction, and the Deeside line if a train is on the single line between Cults (the first station on the Deeside line) and Ferry Hill junction. This is because there is no proper loop on the Deeside line long enough to hold a train at Ferry Hill junction, and the train could not be kept standing on the main line at the junction until the train from Cults had come off the single line. I understand that it would be by no means a difficult matter to make a proper loop on the Deeside line at Ferry Hill junction, and it seems most desirable, for the purpose of facilitating the traffic, that this should be done with the least possible loss of time. As the rule directing that a five minutes interval should elapse between following trains and engines appears not to be observed by the signalman at Ferry Hill or Denburn junctions, there should certainly be special authority given them to depart from it. Nothing is more destructive of discipline than the existence of rules which are habitually neglected.

Major-General Hutchinson has reported the result of his inquiry into the circumstances connected with the collision which occurred on the 28th July last, near Balado station, on the North British Railway. This collision, in broad daylight on an open part of the line, between a passenger train which had just started from Balado station and a goods train which had left Kinross junction, two miles from Balado, at an interval (as stated) of six minutes after the passenger train, was caused by very gross negligence on the part of the driver of the goods train. He had been waiting at Kinross junction for the passenger train to precede him, and must have seen it start. There is but little reason to doubt that the Balado distant-signal (930 yards from the station) was at danger when he approached and passed it, though his fireman (the only servant with the goods train whom I was able to examine, the driver being in prison and both guards discharged), states the contrary; and had the driver only looked ahead as he was approaching the station he must have seen the passenger train starting from it. Moreover, according to Rule No. 124, Balado being a station where the goods train had to stop when required, the driver was bound to stop there unless he received a *hand-signal* to proceed without stopping, whereas the only hand-signal exhibited was that of the station-master endeavouring to stop him. Whether or not this recklessness was produced by drink I have not sufficient evidence before me to determine. The Balado station-master is the only witness who speaks positively on the subject, but it is quite possible that the excitement caused by the collision may have helped to produce the appearance of being the worse for drink of which the station-master speaks. Anyway the driver's conduct is most culpable, as he appears not to have been keeping the slightest look-out, and to have had steam on up to within a very short distance before the collision, which would have been much more serious but for the fact of the speed of the passenger train having been some 15 miles an hour. The fireman and guards of the goods train are also to blame for not having kept a better look-out, and the head guard is still more culpable for having been on the engine instead of in his van. It is hard to believe that an interval of six minutes, as stated by the Kinross junction station master, and as shown in the train register, can have elapsed between the departures of the passenger train and goods train from Kinross junction, the times entered being 4.9 and 4.15 respectively. The guard of the passenger train booked the time of leaving Kinross as 4.10 and of leaving Balado 4.16. There is no reason to doubt the accuracy of the guard's entries, and I therefore

think that the goods train must have been allowed to leave Kinross junction at a much less interval than the five minutes enjoined by Rule No. 121, and that the station master is therefore to blame for this, as well as for not having taken the ordinary precaution of informing the driver that the passenger train was immediately in front of him. This collision would not have occurred had block telegraph working been in force. The signal arrangements at Balado certainly admit of improvement. The distant-signals which alone exist are not sufficient for the proper protection of trains standing at the station. The automatic brake with which the passenger train was fitted appears to have done good service. The train was severed into two portions between the second and third vehicles by the force of the collision, and the guard in the rear van having been knocked down, it is most probable that the rear part would have run into the front part, and produced a second collision, had not the automatic action, brought into play by the severance of the couplings, promptly stopped the rear portion.

Colonel Yolland has reported the result of his inquiry into the circumstances connected with the fatal accident which occurred on the 12th July last at the Port Meadow footpath crossing of the London and North-Western Railway situated nearly three-quarters of a mile north of the terminal station at Oxford, when a boy named James Orchard was run over by a down passenger train and instantly killed. From the statements it appears that just before the accident occurred a Great Western down goods train had been shunting and standing on the down main line of the Great Western Railway across this footpath crossing, and 30 or 40 people are said to have been waiting in the space between the two companies' lines to cross them. The two large gates in the centre were both open, while the outer large gates, which fence off the two railways from the adjacent lands, were both closed, and there were two signalmen belonging to the two railway companies in the space between the lines. Immediately before the accident occurred a London and North-Western up goods train, 7.45 p.m. from Oxford, consisting of 25 wagons, was in the act of passing over the footpath crossing; and as the last vehicle, a brake-van, passed over it, a boy darted out of the crowd, who were standing waiting between the two lines of railway, passed over the up line, and was in the act of crossing the down line when he was run over and killed by the 6.35 p.m. London and North-Western down passenger train, which was due at Oxford at 7.45 p.m., and which was apparently running punctually to its proper time. I cannot say that I think any blame attaches to the servants of either of the two railway companies concerned, but the existing arrangements are not such as to provide for the public safety as regards more particularly foot passengers requiring to pass across the two railways at this footpath crossing. The Board of Trade are not authorized to interfere in such a case, and there are no clauses in any of the General Railway Acts that I am aware of for providing for the safety of the public at occupation roads or public footpath crossings. The jury at the coroner's inquest expressed a "strong opinion upon the want of security at the crossing, and the urgent necessity for a bridge over the two lines, and they requested the coroner to forward their opinion to the directors of both companies." But the Jury do not appear to have stated what kind of bridge they thought should be constructed, whether it should be a regular road-bridge or only a foot-path bridge. As I have already stated, there is no road of any kind leading to any place on the western side of the Great Western Railway. The occupation road ends immediately the Great Western Railway is crossed, and unless the road authorities are prepared to construct a new road from the present termination of the occupation road in some direction, it would be ridiculous for an officer of the Board of Trade to suggest the construction of a road bridge over the two lines of railway. It is not required. The case is altogether different as regards the public foot-path crossing, as, with the very large number of persons (10,000) who are said to make use of this crossing on certain occasions, it would, in my opinion, be highly desirable that the London and North-Western and Great Western Railway Companies should take into consideration the expediency of erecting a foot-bridge across their lines of railway at the Port Meadow crossing. Until this is done, I think the Great Western Railway Company should take steps to do away with any necessity for shunting their goods trains at such a distance from their station; and that both railway companies should not permit vehicles to pass across their lines on the level at this crossing, which have no right to do so.

Colonel Yolland has also reported the result of his inquiry into the circumstances which attended the accident that occurred in the Paddington station-yard of the Great Western Railway on the 23rd July last, when a shunting tank-engine got off the rails, turned round to the right, and fell over on its left side, injuring two of the Company's servants, one of them rather severely. From the statements, and from an inspection of the spot where the accident took place, it appears that as a tank shunting-engine, No. 866, was drawing a six-wheeled brake-van and two carriages out of No. 8 line at the Paddington station, running with the chimney in front, it left the line on which it was running and passed on the wrong side of a fixed point on the outside of a sharp curve of less than 5 chains in radius; which fixed point is about 7 feet 9 inches in front of a self-acting single-point, weighted to stand open for the cross-way road, and the left leading wheel of the engine shortly afterwards mounted the self-acting single point, and the engine got entirely off the rails. It is stated to have been running at the ordinary speed at

which the shunting operations were performed, of from 8 to 10 miles an hour, but from the damage done to the engine it was probably more, and after running for about 57 yards it turned sharply round to the right, and fell over on its left side. According to the plan supplied to me by the company's engineer, Mr. Prickett, the fixed point on the narrow gauge line, on which the engine and vehicles were running, is at the commencement of a sharp curve of about 5 chains radius. The shunting-engine which was drawing these vehicles was a six-wheeled coupled saddle-backed tank-engine with 16-inch cylinders, the diameter of the wheels being 4 feet, and the distance between the leading and driving wheels being 7 feet 4 inches, and 6 feet 4 inches between the driving and trailing wheels, making up a total wheel base of 13 feet 8 inches. The weights on the leading wheels being 11 tons 4 cwt., on the driving wheels, 11 tons 4 cwt.; and on the trailing wheels, 9 tons. The end of the fixed point was struck by the leading right wheel of the engine, which then passed on the right side of the fixed point on the outside of the curve, and the left wheel appears to have mounted the movable single switch, nearly opposite to the fixed point. The brake-van and two carriages travelled on their proper road, but the leading vehicle was pulled off the rails, and the engine coupling was broken just as the engine was turning round. The two carriages remained on the rails. The accident was probably occasioned by a sudden jerk while travelling at too high a rate of speed, just as the engine passed over the single movable point, which in this instance only acted as a check-rail. The gauge at the fixed point was about three-quarters of an inch wide, and very properly so; if it had been half an inch wider to gauge, the accident might not have occurred. But the principle of only having a single rail to guide the wheels in going round such a sharp curve is radically wrong, and its use should be done away with. I had occasion, in my report of the 7th April, 1880, of the inspection of the subway, to point out that there were certain fixed points on the passenger lines in the Great Western Company's yard at Paddington that should be done away with; but I am sorry to say that some of these still remain, and I am of opinion that the Board of Trade should call upon the Great Western Railway Company to get rid of these fixed points on passenger lines at once, and not wait until some serious accident at them raises the question of negligence in an unpleasant form. This accident occurred on sidings to an engine and empty carriages, but the warning which it conveys is applicable also to passenger trains travelling on passenger lines.

Colonel Rich has reported the result of his inquiry into the circumstances connected with the collision that occurred on the 6th August last at the Garrison Lane Junction on the Midland Railway. The collision was caused by the mistake of the pointsman on duty at Garrison Lane junction, who appears from some unaccountable reason to have taken it into his head, that the passenger train to Gloucester was being sent along the main line from Gloucester, instead of being sent through the sidings, as he had been distinctly and properly informed that it would be about 10 minutes before its arrival.

NOTES.

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An error which we much regret occurred in our abstract of the Board of Trade returns last month. By the omission of a cypher, the faults of the Westinghouse Automatic Brake appeared as 1 in 2,397 miles. It should have been 1 in 23,970 miles.

The Brighton Town Council, at their late meeting, resolved to petition the directors of the London and Brighton Railway to run more third class trains between the two termini.

It is stated that Mr. Alexander M'Donnell, locomotive superintendent of the Great Southern and Western, has been appointed to the North-Eastern of England, and Mr. Aspinall, who was next to him, has been promoted to the chief command over the Inchicore works; Mr. Joatts, who superintended the works at Cork, being brought up to Inchicore, to fill Mr. Aspinall's late position, and Mr. Smith being placed over the Cork works.

A New Speed Recorder.—A special train, consisting of an engine and one coach, made a run of about fifteen miles out from Kansas City and return, over the Fort Scott and Gulf Railroad, for the purpose of testing an invention, destined to gauge and register the speed at which a train is running. One of the machines was placed on the engine and one in the car. *The Chicago Railway Review* describes it as consisting of a dial like that of a steam gauge, with an index which marks the increase or decrease of speed, and a registering instrument something like an anemometer used by the signal service for registering the velocity and direction of the wind. This register is furnished with a coil of paper divided into squares by lines, those running lengthwise, 60 in number, showing the height of speed, and the transverse lines dividing the record off into miles. During the trial trip the train ran at various rates of speed to test the velocimeter. The gentlemen who watched its workings were greatly pleased with it, and pronounce it a valuable invention.

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WEBB'S THREE-CYLINDER COMPOUND LOCOMOTIVE.

WE have received the following from Mr. F. W. Webb, Locomotive Superintendent of the London & North-Western Railway, relating to his Three-Cylinder Compound Locomotive, of which we now give drawings on Plate CLXX.

"I had two main objects in view when designing this engine: 1st. Greater economy in the consumption of fuel. 2nd. To do away with coupling rods, and at the same time obtain a greater weight for adhesion than would be possible on one pair of wheels, without rapid destruction of the road. With the exception of the third cylinder, which is very simple in construction, there are fewer parts in this engine than in most coupled engines, as I have three connecting rods instead of the two connecting and two coupling rods, as in our ordinary engines; also by using the motion designed by Mr. David Joy, I have been able to do away with the use of all eccentric rods in this engine, again considerably reducing the number of the working parts for the valve gear. The first engine I built on this principle has two outside high pressure cylinders 11½ ins. in diameter, and one inside low pressure cylinder 26 ins. in diameter, the stroke being in both cases 24 ins. It has now been at work six months, and has up to the present time run over 43,000 miles with our Irish and Scotch Limited Mails. The mileage obtained is more than what we are accustomed to run in the time, and to meet it, I have had to have two different drivers, one going from Crewe to London and back one day, and the other on the following day, the daily mileage being 319. I have taken a large number of indicator diagrams from this engine while actually at work, and in the new compounds I am now building, I have increased the diameter of the outside cylinders from 11½ins. to 13ins., keeping the inside cylinder the same diameter as at present, as I find from the diagrams, that if my outside cylinders were a little larger, I could expand the steam to a greater ratio in the first pair of cylinders than at present: the usual point of cut off when working at speed on the line now being half stroke in the high pressure cylinders. The commercial results with this engine so far have been very satisfactory, and during the last three months the engine has been running our Irish Mail from Crewe to London, and our Limited Scotch Mail from London to Crewe, on an average consumption per train mile of 26.6 lbs. of coal, compared with 34.6lbs., the average consumption of our standard four-wheel coupled passenger engines, with 17in. cylinders and 24in. stroke, the boilers being precisely the same in both cases. The only difference being that in the compound I have only half the number of blasts for urging the fire, compared with what I have with the ordinary engine. Nevertheless, the compound steams very freely, and I am enabled to run with a blast pipe 4⅞ins. in diameter for the final exhaust from the low pressure cylinder, compared with 4½ins. in our engines of ordinary construction."

NOTE ON AN IMPROVED PERMANENT WAY PROPOSED BY M. BERGERON.

IF we were to watch a length of the rails upon which fast trains are running, we should observe the sleepers, upon the passage of a train, embed themselves in the ballast, and rise again as soon as the train has passed. The rails also sensibly fall and rise. The lengths of rail, being united by the fish-plates, make a continuous bar, resembling, so to speak, part of the chain of a suspension bridge, and the vehicles running upon it experience oscillations analogous to the rolling of a ship. It sometimes happens that in repairing a road the workmen pack up some of the sleepers without touching those on either side; consequently on the passage of a train the latter sink, while

the former being freshly packed are able to offer a resistance to the downward pressure; thus the rails from one to the other form perceptible inclined planes, which cause considerable oscillation to the train passing over them. In rapidly descending one of these inclined planes and rising that which follows, the wheels of the train have a tendency to quit the rails, more especially if running round a curve. This tendency is proportional to the speed of the train, and if this is very great, derailment is nearly inevitable. Colonel Yolland, of the Board of Trade, reporting upon accidents occasioned by derailment, states that they mostly occur at places where the sleepers have been thus raised.

They are also occasioned by bad ballast beneath the sleepers, that is to say, if it contains a large proportion of fine sand, the particles of which being very mobile, are not able to offer any resistance to the downward pressure of the sleepers. With bad ballast it is impossible to guarantee the safety of fast trains. It is for these reasons that the engineers of most of the large railroads, especially in France replace the old blast by flint, or stones broken to the size of those used on a Macadamized road. The elements of this ballast are much more difficult to be displaced than those of sand. After the sleepers are once bedded they have no further tendency to sink, and the chances of derailment are diminished as long as the rails remain firmly attached to them. This condition is easily obtained with new sleepers, but not so in the case of those which have been exposed for some time to the weather, which rapidly rots the sleepers resting on this ballast. They become completely soaked with each shower of rain that falls, and by the action of the sun's rays and the free circulation of air through the ballast beneath the sleepers, they soon become rotten, and the dogs no longer hold, thus causing the normal gauge of the rails to become altered. In this state of things derailments may certainly be expected. I am able to state, from my experience of the numerous renewals of sleepers upon the railways of which I have have had the direction that those embedded on sand or fine gravel last twice as long as those resting upon ballast, which is permeable to water, air, and the sun's rays. I fear that the companies whose engineers employ stone as ballast upon roads with Vignoles rails, will soon be under the necessity of buying new sleepers to replace those not already perished. This will be a heavy charge on these companies, for wood becomes dearer and dearer every day.

An English engineer has lately calculated the number of sleepers required every year for the repair and construction of the railways upon the globe, and he estimates it at forty millions, and this number increases every year. It is, then, to the interest of the companies, and still more to that of the countries who wish to preserve their forest, and stop the demolition of their mountains, to replace the wood sleepers by some kind of metallic support for their railways.

I will not stop to describe the different systems of sleepers in wrought and cast iron which have been used with more or less success of late years in Germany, Egypt, India, Australia, South America, and even at Middlesborough in England. I must, however, just mention the oval cast-iron sleepers of Mr. J. Livesy, of which more than 200,000 tons have been used within the last fifteen years. They have proved so satisfactory that MM. Lavally and Molins have bought 60,000 for the L'Ile de la Réunion Railway, and at the present time the works of Messrs. Anderton, at Glasgow, have received from them an order for 100,000 more to be delivered within the present year. I regard this system of sleeper as the most economical and advantageous that has been invented up to the present time. It is to him that I owe the idea of my rectangular cast-iron sleepers, which have been already described in the August number of the *Railway Engineer*, and also before the Society of Civil Engineers in Paris.

Since then, by the advice of critics, and from observations that have been addressed to me by several engineers, above all, by my friend Mr. Livesy (whose ability and experience I highly value), I have introduced some modification in the method of attaching the rails to the sleepers. Without examining the particular reasons for so doing, I will limit my article to a description of the new permanent way represented on Plate CLXXII., Fig. 1 is a plan; Fig. 2 a sectional elevation through A B; Fig. 3 a sectional elevation through C D; Fig. 4 section through E F; and Fig. 5 a transverse section of the permanent way.

I have before mentioned, and repeat again here, that compressed sand is the best material that can be used for the foundation of a railroad. The anvils of the most powerful steam-hammer used in our large factories rest upon layers of sand, which compress and expand under the blows of the hammer like a very dense liquid without change of form or nature. The paving and curb-stones of the streets of large towns also rest upon sand. We may, therefore, compare the sleepers when they are embedded in sand to a series of anvils, presenting also their resistance and elasticity. Under these conditions, the roadway they have to support will be firm and steady, no matter what the speed and weight of the locomotives running upon it. The top plate of the sleeper has four holes, by means of which we can ascertain the condition of the sand beneath; and, if it is necessary, we can ram fresh sand through these holes by means of tools resembling a caulking-tool.

I have supposed that we employ double-headed rails of the section known as bull-headed. They present as much resistance, while weighing less, and bending more easily than the Vignoles. Owing to the short distance of 1 ft. 4 in. between the sleepers, we need only make the rail 4 in. high and a weight of 50 lbs. per lineal metre. The top head of this rail will have a section equal in area to an ordinary double-headed rail which weighs 80 lbs. per lineal metre; thus it will offer just as much resistance, and last as long as

this rail, while if it becomes necessary to take it up, there will only be 50 lbs. instead of 80 lbs. of steel to throw away. In Figs. 2 and 3 we see the lower part of the rail rests in a groove running the whole length of the sleeper. The projecting jaws in the centre of the sleeper are cast with it, and serve by means of an oak wedge to secure the rail at the proper inclination in the same way as in the case of an ordinary chair. When it is necessary to change the rail we take out the bolts at the joint and knock out the wedges. This operation is the quickest and most simple we know of for renewing a permanent way. It is rendered thus easy because there is no part of sleepers which it is necessary to alter. When the rails are set we scatter over the road a layer of mould, upon which we place grass turfs.

I have not thought it necessary to point out the advantages derived from a saving in the wear and tear to the rolling stock, and which result from the use of these sleepers, as they are too evident. I contend that by the means above indicated we may obtain a regular, solid and durable permant way ; it remains for me to show that it is also more economical than all others. For this purpose I will give the work to be done, with the price to be paid for it, of all the parts of the new permanent way.

I shall consider that in all cases we have the platform all properly levelled for laying the rails. Below each line of rail we dig out a trench 1ft. 8in. wide, and as much in depth, resembling precisely those made to receive the gas and water pipes in large towns. The trenches are then refilled with sand from any river, brook, or pit that may be near the railroad. We may also use sea-sand, or that obtained by passing ordinary ballast through a fine sieve, or if not able to obtain sand, we may use the powder obtained by crushing stones by special machines. The fine earth which support the chairs of Grieves in Egypt, and Livesy in South America, would also serve to refill the trenches. As in Europe we are continually using sand to make mortar for building purposes, we shall always find it convenient to use this material for the foundation of the sleepers. The sand is then saturated with water and wel rammed down, which will cause the grains of sand to be so pressed upon one another that the rain water will run off the surface as off that of an ordinary Macadamized road. Two of the inverted cast iron troughs, held together transversely by means of flat bars equal in length to the normal width of the road, as shown in Fig. 5, I propose to substitute for the ordinary sleepers. They are placed on the walls of sand at their proper places. On the top plate, on the right and left of the vertical projections, we place two blocks of wood to protect the cast iron from the blows of the mallet. Four workmen, two to each sleeper, then strike the blocks at the same rime with very heavy mallets. The inverted sides of the trough being brought to a point, sink in the sand under the blows of the mallets, just in the same manner as an iron-shod pile. This operation should be performed cautiously. All the troughs for a length of rail should be embedded at the same time, and care taken that all the top plates are in the same plane. There will be a sleeper at each distance of 3ft. 4in., and as the troughs are 2ft. long there will only be a distance of 1ft. 4in. between the ends of each sleeper.

The fish plates descend below the foot of the rail, and butt against the ends of the troughs, so that they offer absolute resistance to the longitudinal slippings of the rails. Having fixed the sleepers, the work of securing the rails presents no difficulty. Then, I affirm, we shall have a permanent way so well laid that the heaviest locomotives, and the trains they draw, may pass over it like a sledge upon ice, at the rate of 100, 120, and 150 kilometers per hour.

We will now see what this road will cost. In ordinary roads a length of rail is 9 metres, I will therefore estimate the cost of a length of 9 metres of the new road which necessitates the use of 9 sleepers.

1st. *Cutting the Trenches.*—The trenches, resembling those used for the gas and water pipes, will not cost more than 50 centimes per lineal metre. The 18 metres will not, therefore, at the most, cost more than 9 francs.

2nd. *Filling the Trenches.*—The sand will not cost more than ordinary ballast, which is 3 francs per cubic metre. The laying it, under the conditions mentioned above, will necessitate a further cost of 2 francs per cubic metre, making a total of 5 francs per cubic metre. That contained in the trenches will be 50 cubic centimetres per lineal metre, which for the two trenches of 9 metres each, will give a total of 4.50 cubic metres, and 4.50 cubic metres at 5 francs per cubic metre will equal 22.50 francs.

3rd. *Metallic Sleepers.*—The weight of each sleeper will be about 45 kilogrammes, *i.e.*, 90 for the two. At the present time in England ordinary chairs are sold at 75 francs per ton. I have reason to believe that the cost of the new sleepers will not be more than 100 francs per ton. Thus the two sleepers will cost 9 francs, and the 9 sleepers will therefore cost 81 francs.

4th. *The Transverse Distance Bars.*—Each bar weighs about 10 kilos. There are two for each sleeper, consequently 18 for the 9 sleepers of the section. They will weigh, therefore 180 kilos, and being of ordinary iron, which at the present time costs 16 francs the 100 kilos, they will cost 28.80 francs.

5th. *Split Pins for connecting the Distance Bars with the Sleepers.*—There will be 4 for each bar, consequently, in all, 72. Each will not cost more than 10 centimes, and thus the total cost of them will be 7.20 francs.

6th. *Bull-headed Steel Rails.*—I have explained above how that the rails weigh only 25 kilos per lineal metre; therefore the 18 metres will weigh 450 kilos, and at the price of rails which is quoted in the market as 16 francs the 100 kilos, the cost will be 72 francs.

7th. *Laying the Road.*—The ordinary cost of laying the

rails is 1 franc per lineal metre. If we compare the work done in laying the metallic sleepers and rails with that of ordinary road, I think I may say that mine will not be at any rate more expensive. However, to meet any objections that may be raised on this score, I will put the cost of laying the metallic sleepers and fixing the rails at 2 francs per lineal metre. The cost under this head then will be 18 francs.

8th. Eighteen oak wedges at .03 centimes each will cost 5.40 frs.

The following table will give a summary of the different items mentioned above :—

	Francs.
1. Digging the trenches	9
2. Refilling the trenches	22·50
3. Metallic sleepers	81·00
4. Distance Bars	28·80
5. Split pins or keys	7.20
6. Steel rails	72·00
7. Laying the road	18·00
8. Eighteen oak wedges at 0·30 each =	5·40
Total cost	243·90
Which per lineal mètre ... =	27·10

We will now place alongside this the cost of laying the permanent way with wood sleepers actually in use upon some of the large railways in England and France.

1st. The cost of the road with double headed rails as adopted upon English railways.

	Francs.
1. Ordinary ballast of sand or gravel 2 cubic metres per lineal metre of road, *i.e.*, 18 cubic metres at 3 francs per cubic metre ... =	54·10
2. 12 sleepers at 5 francs each =	60·00
3. 24 cast-iron chairs weighing each 20 kilos, equals 480 kilos in all, at 10 francs the 100 kilos ... =	48·00
4. 72 iron pins to fasten the chairs to sleepers, at 30 cents each	21·60
5. 18 lineal metres of steel rails weighing 40 kilos, per lineal metre—720 kilos, which at 16 francs the 100 kilos	115·20
6. 18 oak wedges ... ... =	5·40
7. Laying 9 metres of the road at 1 fr. per metre ... ... =	9·00
Total cost	313·20
Which for 1 metre ... ... =	34·80

Cost of laying a road with Vignoles Rails, as carried out in France :—

	Francs.
1. Selected ballast of flint or broken stones—18 cubic metres at 3.50 frs. per metre ... ... =	63.00
2. 12 Oak sleepers at 6 frs. per sleeper=	72.00
3. Rails, weighing 40 kilos per metre, *i.e.*, 720 kilos in all, at 16 frs. per 100 kilos ... ... =	115.00
4. 48 Iron pins at 30 cents each =	14.40
5. Laying the road	9.00
Total cost	273.60
Which for 1 lineal metre ... =	30.30
Thus the cost of the road per lineal metre, using double-headed rails with wood sleepers, is...	34.80
That of the road with Vignoles rail, wood sleepers, and stone ballast	30.30
That of the road, with metallic sleepers, which I propose	27.10

We see then that it is more economical in the first cost of laying a permanent way to adopt the system of metallic sleepers, which I propose. It will be infinitely more so when we take into account the cost of keeping it in repair, which is enormous with roads using the wooden sleepers, and practically nil with the others. This is so evident that it is useless for me to particularize the advantages secured under this head. I have thus, it seems to me, given good reasons for the adoption of my system of permanent way by railway engineers.

THE NATIONAL EXHIBITION OF RAILWAY APPLIANCES.

THE Darlington Exhibition, we are glad to announce, was a great success. Lasting for five days only, it was impossible that its promoters, the Amalgamated Society of Railway Servants, could recoup themselves for the great outlay indispensable to an effort of this kind, but the purpose of the effort was entirely effected in the attention they drew to the existence of appliances calculated materially to reduce the dangers to which railway servants are hourly subjected, and, we hope in no small measure, to convince their superiors of the necessity for the adoption of those considered most suitable to the circumstances. So large was the number of entries that the Committee was driven to the greatest straits to find room for all; while many were, through their late arrival, excluded from the catalogue. Having in our last issue explained the objects of the Exhibition, and pronounced an emphatic opinion upon its value, it will be sufficient now to give a description of the exhibits, so far as our space permits.

CLASS I.—CARRIAGE AND WAGON COUPLINGS AND COUPLERS.

THE DOUGLASS PATENT COUPLING.—Blaydon-on-Tyne.—This is the simple and effective coupling we have described in former issues. The last link has a curved bar across the middle, forming a sort of handle, into which the person engaged in coupling or uncoupling inserts a hook fixed on the end of a pole, raising or lowering it as required. The operation will be found illustrated in our advertising pages. *Special* First-Class Certificate. Some interesting and valuable experiments took place with these couplings, on the 25th and 26th inst., at the Euston Terminus. The Messrs. Douglass were requested by a number of influential gentlemen to arrange for the practical illustration of their invention at some central place, and, by the courtesy of Mr Findlay, they were enabled to have two wagons with an attendant at Euston during Wednesday and Thursday last. These were visited by numbers of gentlemen, who universally expressed their pleasure at the extreme simplicity and perfect efficacy of the contrivance. We learn that the London and North-Western Railway are fitting their stock as rapidly as possible with the Douglass couplings, and the inventors are not without hope that other companies will follow in their footsteps, so that the great network of English railways will be uniformly supplied with the same safety couplings and poles.

MR. WILLIAM CROMBLEHOLME, Salford, exhibited an apparatus for connecting and disconnecting railway carriages and trucks. It consists of two hooks and two bridles, one bridle fixed to each cross-bar, forming the end of the frame of the carriage or truck, and a block of india-rubber or other spring introduced between the end of the bridle and the cross-bar to act as a draw spring. The hooks are jointed to short shafts supported in bearings in the said cross-bars. Under each hook is a shaft having a spur pinion gearing in a pinion on the shaft of the hooks, and to each shaft is fixed a lever, which is held in position by a spring catch or otherwise. When the carriages or trucks are brought together the hooks spring over the ends of the bridles and catch into them to connect the carriages, and when it is necessary to disconnect the carriages the levers are turned partly round, by which means the pinions release the hooks from the bridles.

T. S. FIELD, London.—This coupling consists of a double link attached to the ordinary draw bar and coupling on to the ordinary hook., the lower link being raised by means of chains passing through blocks on the end of the wagon to the buffers or other convenient place on either side, the upper link being moved outwards by means of a lever on a way shaft passing under the wagon, with levers at the ends for working it from either side. Wagons fitted with this gear can couple to any wagon in ordinary use without anyone going between them.

CHARLES KAYE, Lockwood.—This coupler consists of a lever worked under the wagon buffer, having a three-pronged fork on one end, one prong to be placed, when coupling, on the top end of the bottom link, and the other two prongs below, one on each side. The fulcrum is formed by a revolving swivel on the lever, attached to a light chain, which has an anchor at the other end, to be placed on the top of a dead-buffered wagon. If spring-buffered, the chain to be thrown over the buffer, and the anchor hooked on to the lever. Then, by a swing of the lever, with one hand the coupling links can be lifted on or off the adjoining wagon. By hanging a small lamp on the lever, this implement can be used by night as well as day. It is all iron, and weighs 9lbs.

W. MAWLAM (Roger & Co.).—This coupler instrument requires no alteration in the existing coupling chains; each workman employed requiring one instrument only. It has been largely used for some years on the North-Eastern Railway, and no accident has occurred when it has been in use; the work is also more rapidly performed.—*Prize Medal.*

GILBERT'S PATENT, Paris.—The Gilbert Coupling Draught is composed of two cases, of three compartments, containing springs, each of two double traction bars and of two working dowels, maintained by four rods with joints, two supports with levers, and lastly provided with a ratch apparatus. The general weight is about 2½ cwt. The compartment in the centre of each case contains springs, is provided with a hook intended to receive in a transitory way the actual coupling; the one on the right contains the fixed end of a double traction bar; the left one is intended, when two wagons are coupled to receive the free end of this double bar, which sets to work a support with levers, the links of which then receive a working dowel, which completes the coupling. The rods with joints lift the working dowels for the unhooking. The ratch, worked by a click, commands a toothed spring wheel and a screw with inverted threads, the inside screws of which forming a whole, with the two parts of the traction bar, gives a reasonable fastening. All these arrangements take place at the outside of the wagons, and in no case is it meant for the workmen to go between the buffers.

M. BAINES, Northallerton, Yorks.—This coupler is adapted for use over the buffer, having much leverage and power over the coupling in that position. The operator can handle it with ease and accuracy, even where stiff couplings are found. He need not go between the wagons, having sufficient power at his command to overcome this by his grip and leverage. In addition to this, it can be used under the buffer with the greatest freedom. This coupler is adapted to nearly all railway wagon couplings now in use.—*Second Class Certificate.*

H. J. JOBSON, Poplar, The "Jessie Automatic Coupling."—By the aid of this invention the wagons couple automatically, and are uncoupled by the workmen by depressing the lever at the side. Place the thumbs lightly on the weight,

and push the two platforms till the spring buffers are three parts home, it will then be seen that the slip raised by the coupling bar, which, on passing it, drops through into the block, and prevents the bar from coming out ; it will then be seen the coupling is effected. To uncouple the locking bar is lifted out of the quadrant, which raises the jaw, and this allows the wagon to be uncoupled from the side.

Wm. Thacker Hole, Chester.—Automatic coupler can be worked from either side of wagon by moving a handle at at the end of the cross-bar. This bar is acted upon by two rods working upon a pin in the lever which can be drawn out or in to suit distance between wagons; also with the same movement of handle the rods carrying a link are lifted and dropped upon draw-hook of wagon, its one weight keeping it down, thus obtaining perfect safety to operator and security to drawing power of wagon.

T. Attwood Brockelbank, Shepherd's Bush.—Automatic Railway Couplings.—Working models of engine and brake, exemplifying apparatus tightening vehicles. Three wagons fitted with centre buffer connection or wagon couplings, also latest improvements of apparatus. A road tramcar, shewing automatic central buffer for mechanical traction. The latest development of this apparatus is as follows :—Coupling irons, identically alike, are attached to draw hooks of almost regulation pattern, on contact with each other duplex grapplers of one or the other secure the connection. Independent of either draw hook or coupler is a releasing apparatus, which either disconnects, holds, or resets the coupling at will.—*Prize Medal.*

R. Hill, Heywood.—Improved "Anchor" Automatic Railway Wagon Couplings.—The inventor claims for these couplings, certainty of self-action, as whether on a gradient or on a curve, and, whether laden or unladen, the mere coming together of two wagons will cause them to be double-locked to each other. Absolute safety to shunters, as by a lever on either side of the wagon a man can instantly loose the couplings without going between them. The couplings for each end of the wagon are exactly alike. No springs or other complications. They can be attached to other wagons not fitted with these couplings in the ordinary way.—*First Class Certificate.*

Jas. Richardson & Son, Liverpool.—Brown & Esplin's Patent Coupler and Uncoupler for Railway Vehicles.—The ordinary coupling chains are suspended, and half the labour thereby saved ; to complete the work give the chains a slight lift, and the operation is complete. When uncoupling, the end link of chain is lifted up and folded ready for immediate use. The coupling chains being suspended, all accidents and injuries to the permanent way are done away with. A pole about 4ft. 6in. in length is used for coupling and uncoupling.

George R. Snowden, Bradford.—A peculiar construction and arrangement of safety couplings for railway rolling stock, whereby the operations of coupling and uncoupling are automatically performed with absolute certainty, from either side of the wagon or vehicle, without the necessity of the entrance of the attendant between the wagons or vehicles. Levers are employed, having bent up projecting ends secured on the draw-hooks. By means of rods fitted on each side of the wagons are secured handles which actuate when required by the attendant, bringing the levers together and coupling the wagons.

Young & Glover, Wolverhampton.—Automatic Coupler. —Claims to be an invention on an entirely new principle, working automatically, is easily fixed, works by its own weight, and perfectly adapted for curves on railways ; is perfectly secure as to drawing power, and easily detached.

James Hill & Son, Huntingdon.—Patented Coupling Apparatus. Can be fixed on the ends of present wagons, without any alteration, and the apparatus attached to present couplings. It consists of an universal action of lock, shackle, link, joint lifting arm and bar, folded or socket handles, central and side guides ; can be used at either corner of wagons, and effect a single or double coupling without the person going between them.—*Second Class Certificate.*

Charles Lord, Huntingdon.—The principle of the invention is to couple a wagon or carriage by turning a spoke wheel and pulling a lever. By releasing the lever the wagon is instantly coupled, and if the same is done at the next truck it is doubly-coupled. The tightening apparatus is also worked with spoke wheels at the side of the wagon, so that no workman need go between trucks.

D. McDermid, Darlington.—Safety Couplings.—By this invention a train of any number of wagons or carriages can be instantly coupled and double-locked, or uncoupled, without the dangerous necessity of crossing the metals. It is worked by handles at the sides of the train, is simple, strong, and inexpensive.

J. T. Leighton, Edinburgh.—Automatic Double Coupling.—This coupling consists chiefly of a vertical link of peculiar form, capable of a certain lateral motion, and a horizontal hook, loose on its axis, but held in position by a moveable block. The block is operated on by means of a chain attached to a rod running across the end of a wagon. To each end of this rod a lever handle is attached. The simple act of bringing the wagons together couples them securely by a double-coupling. They are uncoupled by raising the lever handles at the sides of the wagons, thus lifting the retaining block out of its bed. The hook is then left free to turn, offering no resistance when the wagons are separated, and remaining in position for coupling again without further attention, except that the handles be left turned down to allow the block to drop into its place when the hook is pushed back into the locked position by the approaching opposite link. Wagons of varying height, loaded and unloaded, are coupled by this method, and the old form of coupling can be used in connection with it.

Hook and links being provided underneath for this purpose.

G. Hopkins, Kensworth.—Patent Railway Couplings.—This invention consists of a lever or bar running across the body of the vehicle, free to move in bearings attached to the outside of the buffers or wagon. This lever or rod is cranked at or about the centre, and to it is attached a sleeve or socket, which is also secured on the reverse side to an arm or spindle attached (free to move) to the under-framing of the vehicle. In this sleeve or socket works a rod forked at the opposite end to carry the end link of the coupling, the other links being attached in the ordinary way to the end of the draw-bar carrying the hook. The end link, however, is formed with a slot in which works a pin on the forked arm. The wagons being brought together, the handle is put in motion by lifting the crank, the forked arm carrying the end shackle up to and over the hook into which it drops, and the coupling is complete. The handle is retained, when the coupling is not in use, in suitable stop or bracket as required.

Thomas Williams, Stockton-on-Tees.—This is an overhead coupling arrangement, consisting of a shackle and two straight links forming a joint, carried off and on wagon hook by two slot links, connected to a weigh-bar, which is placed immediately beneath buffers. No. 2 arrangement is also an overhead coupling similar to the above, where the front link with two pins projecting, one at each side, is carried off and on wagon hook by two jointed forked levers connected to a weigh-bar, the centre link being supported by stay fixed to the forked levers. This plan is specially suitable for block trucks. In both cases there is a lever at each end of the weigh-bar, which can be fastened or unfastened at either side when working the coupling. Both these couplings can be worked from the engine by a lever placed on driver's platform.—*First Class Certificate.*

H. Hawgood, A.M.I.C.E., Highgate.—Patent.—Wagons can be coupled or uncoupled by using the lever fitted on either side of the wagon. The draw-bar and hooks of the present rolling stock in use on railways can be adapted to this invention, or used in conjunction therewith. Should this coupling be thrown short of the hook of the wagon to be coupled, through being too far apart, another turn of the lever will raise the coupling, and put it into position for use. The coupling could be adapted for coupling or uncoupling a train of wagons from the engine, by the driver, without the aid of a shunter.—*Second Class Certificate.*

R. Stowe, Bristol.—The following advantages are claimed for this invention:—Any number of carriages can be instantly attached or detached, standing, or running at any speed, or at any point. Security and simplicity in locking, impossible of becoming unlocked. Straight pull on curved line, and broken pull no impediment. Great saving of time and labour.

R. Baldwin, Cheltenham.—Balance Coupling.—Acts automatically, and, in case of runaway wagons, can be caught up by engine furnished with the same appliance, under control of driver, without the assistance of shunter.—*Second Class Certificate.*

J. P. Davies, Chester.—Improved Couplers.—No. 1.—A rigid or stiff coupling formed by a shackle keyed on a through bar extending from side to side of wagon, dropping on to pin on the adjoining wagon, worked by a lever outside of wagon buffer. No. 2, is a crank bar made to couple and uncouple existing couplings by a lever outside the buffers. Applicable to existing couplings.

S. Gillaird, Liverpool.—Automatic Coupling.—Ordinary draw-bars are used, having specially shaped hooks, at the ends are screw-threads, working into a block or collar, round which is secured a volute spring, sliding in a cylindrical casing attached to the carriage frame, so that the hooks of opposite carriages can recede upon coming into contact. The screw-threads are right and left for the purpose of tightening or *vice versa.* The slot in body of hook is specially shaped, so that coupling link can be set in position previous to coupling. The coupling action takes place when the link commences to slide up the face of the hook, at the same time disengaging itself from the fixed position in the slot. After passing over the nose it falls into the mouth of hook, and upon the recoil of buffers will be coupled. Uncoupling by compression, having the nose of hook turned downwards, allows link to fall out, or by the ordinary way of unscrewing the draw-bars, the link will come beyond the mouth, and so become uncoupled.

Ibbotson and Talbot, Automatic Couplings, Sheffield.—The wagons coming together, one of the links mounts upon the other, and passing over the coupling-hook drops into its place and connects the wagons. The uncoupling is effected by raising and throwing back the coupled link by the simple lever arrangement worked from the outside of the wagons. When disconnected, the links are supported and held in correct position for coupling by a cap-piece, resting upon the hook, and acts as a strengthening tie to the link. This coupling allows for a difference in height of vehicles of 7 inches, and is suitable for any curve of a radius of 2 chains and upwards.—*Prize Medal.*

S. Gilbert, Jun., Mansfield.—Automatic Coupling.—The coupling consists of two hooks or clasps, one at each end of each wagon, which are self-locking when the wagons are driven together, and which are released by a hand lever worked from either side, and are kept in position by the united forces of traction and a counterbalance.

C. C. Braithwaite, London.—This consists of a device whereby the last link of a coupling chain attached to one vehicle, can be grasped and passed over the hook of an adjoining vehicle, or may be lifted therefrom. This coupler is adapted for use with all existing coupling chains.—*Highly Commended.*

J. Waddington, London.—Gedge's Patent Wagon Coupling.—The draw-hook is similar to those now in actual

use, excepting that a slot is cut in the upper side of the hook into the shackle pin hole, through which the top link of the coupling chain is passed into position by means of a flattened portion of the link, which, however, contains the same sectional area of iron as the remaining portion of the link. The area of iron taken out by the slot is distributed on the under side of the hook, causing no loss of tensile resistance. In case of the fracture of a coupling a guard or shunter can easily and at once replace it without dividing the train. It is impossible for the chain to get out of the draw-bar itself or be jerked out in shunting. In ordinary shackle couplings the pin often bends and binds in the hole, causing the shackle to remain in a horizontal position. By Gedge's method that great fault is overcome.

J. Manifolds, Liverpool.—This coupling is automatic in action, and consists of a screw, which on the colliding of wagons, worms itself through the beam of the wagon and locks inside.

R. Lansdale, Halewood.—Automatic Coupler.—In this invention an iron bow is the hold-by and rigid; a half harpoon pointed hook, working on a hinge on the other wagon, when the wagons come together the hook strikes the bow, rises and fastens itself, then. if requisite, the hook is locked by a handle placed on the side of the buffer—the same handle serves for uncoupling. The arm of the hook is supported by the bow of the wagon it is attached to. A rod crosses the buffers, from the centre of which is a finger running under a loop fastened on the arm of the hook, by that means the handle on side of the buffer rises or lowers the hook. The handle is kept in position required by a quarter-circle on side of the wagon, or other appliances. The hook acts automatically, and could be unhooked by a stick if required, and the rod crossing the buffers dispensed with.—*Highly Commended.*

S. Humble, Derby, exhibited underframe of 8 ton goods wagon fitted with patent safety draw-bar. The invention consists of auxiliary bars or safety side pins, fitted with either rubber or steel springs, which are attached to the draw-bar and secured to the buffer plank, by simply elongating the shackle bolt of draw-bar and passing it through the eyes of the safety side pins, thus reducing the strain one-half on the main drawbar, and by which arrangement, if the drawbar breaks, the vehicle will still be drawn by the safety side pins, without any undue strain.—*First-Class Certificate.*

J. Skelton, Maryport.—Self-acting couplings having all the advantages of the ordinary chain couplings, besides possessing several others. The trucks are uncoupled by pressing down a small handle placed at each side of a wagon near the buffers. There are handles at both sides and at both ends of the trucks, enabling the shunter to couple, uncouple, and slip at pleasure, without going between the trucks. Small pins can be attached to the handles, so that if at any time they are not required they can be lifted up out the way.

J. Halling, Nottingham.—Improved Coupler.—Is fitted on the end of a shunting pole, consisting of two straight forks of equal length, with four notches on them, two on each fork. One of these forks goes through the middle link, the first notch stopping the middle link; the other fork goes down behind the bottom link, and the notches stop them from slipping from the man that is about to couple the wagons together. It makes no difference how stiff the shackle is, it is strong enough to pull it up the pole until it comes over the top of the buffer.

J. Cottingham, Market Rasen.—Improved Coupling.—Consists of two levers and one link with sheath to receive link.

R. B. Lister, Halifax.—This automatic coupler is connected under the wagons in the same manner as the coupling rods now in use, the drawheads and ratchets superseding the use of the present hook and chain. To uncouple.—Seize handles in each hand and move them towards each other, and the ratchets will be raised by the levers. These levers are connected with tappets which raise the catches and keep the ratches raised so that the wagons cannot be recoupled until required. To couple.—Depress the levers connected with the uprights, which will knock the catches off the tappets, and the ratchets will fall by their own weight into the drawheads, which being levelled to the same angle as the ratchets cannot be displaced by the jerking of the wagons in motion. If there be a curve in the line, the ratchets will be guided into their places by the projecting edges of the drawheads.

B. Askew, Cowlairs.—Patent Coupler.—Is of extreme simplicity, claims to effect economy of time, of cost, and gives perfect security in manipulation.

A. Oxenham, Surrey.—Improved Couplings.—To couple up, revolve the locking plate completely round; then lower the link into position by means of side levers. To uncouple, revolve locking plate, and lift levers. The locking plate keeps the link in position, coupled or uncoupled, all being done from the sides.—*Highly Commended.*

J. C. Davison, London.—Patent Coupling Apparatus.—The parts of this coupling are, as heretofore, capable of being drawn towards each other, or in part removed therefrom, for the purpose of drawing adjoining carriages closely together, or for tightening up, or for releasing them by means of right and left handed screws on a screw stem, which for the motion in either direction is operated by a ratchet brace having a double ended driver rocking on a centre of motion, and acted upon by a spring adapted to act on teeth applied to the boss or collar of the screw stem to drive that screw stem in the direction for the time desired.

W. Simpson, Darlington.—Self-Acting Wagon Couplings.—To couple or uncouple, can be done at either side of the wagons without climbing over or under the buffers. These couplings work equally as well with those at present in use,

and when attached to a locomotive the operator can work it without getting off the engine.—*First-Class Certificate.*

Gough & Son's (Calne, Wilts) showed improved railway wagon couplings attached to two working model wagons. They are so made that they can be welded on to the existing draw bar in the centre of wagons now in use. The invention consists of a rectangular shaped link, inside of which is a one-sided jointed crook, with a lever arm at the end for raising the same; it being acted upon by a D shaped link in the centre of a lever bar running across end of wagon the wagons can be coupled or uncoupled from either side. They cannot become detached when in motion. They act exactly the same if the wagons are reversed.

Francis Kemp, London.—An invention designed for the purpose of effecting self-acting coupling of railway trucks, by merely pushing the trucks together, and to afford a ready means of disconnecting them by a lever placed at the outside, so that there is no necessity for a porter to pass in between the trucks.

E. Wilson, Edinburgh.—When the wagons are brought together they couple momentarily and brace on the buffers, thereby saving screwing up, in relieving them, the side lever lifted throws them out of gear, thereby lessening the risk of life. The coupling looks open, but cannot be thrown out owing to the leverage. At the other side of the wagons there is another coupling for the ordinary trucks now in use, to be fixed on to the ordinary hook that will couple all high and low wagons. In case of accident, such as the breaking of an axle, the coupling would fall clear, and the train would run clear of the *debris*. It would also be a saving of life and plant.

James Dixon, Bedlington Colliery, showed model of two wagons and chain coupling, fitted with jibs and stow to stiffen chains and guide the link to hook.

R. J. Langwill, Sheffield.—Automatic Coupling.—The appliance is a loop, with a hook secured to an iron rod, passing through projectors, with round holes in centre. Square part of rod, fitting into square hole in hook, so that by moving handle at the end of rod it will turn back, the hook effecting the uncoupling. In coupling, the hook is turned down on one of the appliances, the projection on hook coming in contact with loop on another wagon, slides over and drops into the loop and secures it.

T. Summerson, Darlington.—Coupler, with Scott's Improvement.—In this coupler, the chain is lifted by the end of the pole which is inserted at the second link. The steel branch controls the end link. It can be used either over or under the buffers, and as a plain pole for uncoupling purposes.

R. W. Fishburn, Wyandotte, Kansas, America.—Automatic Coupling (J. G. Maris' Patent).—The coupling is performed by the pressure of the link against the point of the hook causing it to rise. The link passes back, and is immediately and securely caught by the hook, thus performing its own coupling, which is always safe, sure, and certain, and may be done by the engineer alone, who can couple a whole train of any number of cars in the shortest possible time and without leaving his engine. Uncouple by raising the lever, which may be done from the platform, or from the top of the car, by a chain or other suitable means. The frog is used to cut a standing train. Raise the lever, turn up the frog by the handle until it catches in the niche.—The engine moves, the link draws out, the frog falls in the slot, and the hook drops to its place ready for the next coupling.

Carl F. Simm, Montreal, Canada.—Automatic Coupling.—The rod for raising the hook for uncoupling can be extended to any desired length, and can be refastened by holding up the hook against the roof, so that the coupling can take place even if the link were in the opposite draw-bar. Entering could also, if necessary, be held down with train in motion, so that there can be no possibility of disengaging, even while in motion.

G. Fenwick, Gateshead.—This invention is an effective method of coupling trucks with any chain now in use, without in any way altering such chain or chains, being altogether apart from the chain when coupled or uncoupled. The appliance is worked from either side of the truck with a hand lever, and when the lever is brought forward the shoe, or lift, which is so constructed, immediately takes hold of the end link of the chain, and the coupling is effected.—*Prize Medal.*

Thomas T. Burall, Thetford.—A Model of Coupling for Railway Wagons. – The invention consists of two rods to each coupling, connected with the pin in the hook, so as to partly revolve it. The rod extends to the outside of the wagons, one on either side, the ends being bent to form a lever. The links are hinged in the centre, one end being fastened to the pin, and revolve with lifting the opposite end off, or on, the hook of the next wagon.

T. Hewick, Derby.—This method of coupling and uncoupling consists of a fork with a long and short prong, having a double hook at the end of the long prong, connected to a socket, in which is fastened a lever of wood. Place the lever on the buffer, put the short prong in the second link, and the long one underneath the first link, prise it up to its proper place, then lower the long prong, and the link falls into the hook. To uncouple, an opposite motion is required, which can be accomplished with ease, and quicker than the ordinary way.

Edward Restieaux, Shrewsbury.—This coupler consists of a long rod, with a cranked fork at one end, to be attached to the long link of the coupling. The other end of the rod, to hang to a crank, the horizontal ends of which to be fixed in loose sockets across the bottom of the wagon. Short lever action in a "quadrant," by the side of the wagon, if turned either way, will couple and uncouple. The length

of bottom link allows for buffers being "dead up," or otherwise.

John Austin, Hednesford.—This coupling pole resembles a three-pronged fork, the middle prong being the longest, and slightly hooked in such a manner as to lift the links of the coupling chain; the outside prongs securely hold the links in any position, and will place the first link on to the hook of the next wagon when in any position. It is necessary to make use of the buffers of the wagon as a fulcrum for the pole.

G. H. Stelling, London.—On the wagons being placed ends together they are effectually coupled and safely locked by one motion only, *i.e.*, shifting a lever a few inches. The lever extending across the end of wagon, having a handle at each end, so that the operation can be performed from either side. On the wagons being reversed, the couplings will fit any end of any other wagon.

R. Robinson, Gateshead, showed a model of locomotive and truck on railway, showing method of coupling and uncoupling from the foot plate of engine by a simple mechanical appliance; suitable for shunting engines. Coupling pole for trucks and other vehicles without any alterations of the present coupling chains.—*First-Class Certificate.*

F. Rowlett, Leicester.—The invention consists of a combination of levers added to the links, so constructed as not to be liable to derangement, and has the advantage of being adapted for use in combination with ordinary wagons without any alteration. The model shows various forms of lever handles which may be indefinitely varied, as experience and convenience dictate. It is claimed for this apparatus—Perfect security from risk of the shunter; simplicity and economy of the arrangement; and the capability of its immediate use as soon as a single truck is lifted up. Trucks with this addition can travel over all lines in combination with ordinary rolling stock.

Henry P. Dowling, Waterford.—This coupling consists of a screw attached by bearings, with its length parallel to the front of the carriage. One half has a right-hand thread the other a left-hand thread. On each half at equal distances from the centre is a nut, which, by means of a pin above and below, can move the ends of the coupling bars towards the centre, or away from it. The other ends of the coupling bars are respectively attached to the two ends of the coupling link by double-jointed attachment, having the two joints working at right angles to each other, thus allowing the coupling bars to turn with the nuts, while the link has a small vertical motion. The nuts have one side grooved to allow of a bar parallel to the screw sliding in the groove as the nuts move along the screw. A handle at each end of this bar enables a man to raise or lower the coupling bars and link when coupling or uncoupling. The screw has a handle at each end. By turning the screw so that the two nuts recede from the centre the link is brought nearer the screw, and the two carriages are thereby tightened together.

Murton and Turner, Harling, claim for Barker's coupling—No danger to men. Works automatically, yet with safety. No need to pass between trucks. Cannot be detached by accident, as it is enclosed on all sides. Under perfect control from either side of truck. The present drawbar is used to fix coupling apparatus, so that in case a truck without the patent coupling needs to be connected no alterations are needed in present form of truck. It can be easily fixed by an ordinary mechanic. Greater despatch in making up train, for if levers are left down driver can by simply "hitting trucks up" couple any number. Each end of truck is fitted with a flat-sided, spear-head draw-bar, and a bell-mouthed cylinder, with rectangular slots, in which work two clutches or jaws. These are kept in position by suitable springs. Thus, if two carriages are brought together the spear-head draw-bars will enter the cylinders by raising the clutches. These will then fall over the shoulders of draw-bar and complete the connection. To effect a separation, suitable levers are placed in convenient positions on sides of truck.

Jabez Evans, Tewkesbury.—Wagon Coupling and Catching Chain.—The coupling and catching apparatus can be fitted to and fixed under the end of wagon on the cross-sole bar. The lifting arm is attached to the bottom or end link of the chain as now used, and his securely fastened to a strong rod under the cross-sole bar. The rod is kept in position by four strong carriers or slips, and when in use forms a means of catching the truck or wagon should the draw-bar come out, or any link break, other than the one to which the lifting arm is attached. The apparatus can be worked with one hand on either side of the wagon, by means of a small lever attached to each end of the strong iron rod under the cross-sole bar, which lever being pressed down lifts the coupling chain, when pulling the lever at the side of the wagon the coupling is effected. The uncoupling is effected by the same easy method.

N. Chandler, Hednesford.—This coupling consists of a a shackle and weighted link. The latter is raised to the desired height by the pulling of a light chain or cord, which passes through a runner or pulley to the side of the wagon, when another cord or chain is pulled, and the link is thrown on to the draw-hook of the next wagon. At the other end of the wagon is another coupling similar to last described, but there is only one cord or chain and a lever to manipulate. The lever extends across the end of the wagon, just above the buffers. This raises the coupling, and the cord with a slight pull thrusts forward the balanced link into the hook of the next wagon. To uncouple it is only necessary to raise the lever with one hand. Both these couplings will act when the wagons are at any distance within reach of the ordinary couplings.—*First-Class Certificate.*

KEETON, New Lenton.—Coupling.—The coupling links are secured to the draw-bar in the ordinary manner by a bolt. A rocking lever shaft is placed across the end of the truck carried by two bearers, to the extremities of which are attached levers forming handles ; in the centre of the shaft projects an arm, attached to which is a lifting link secured to the couplings by means of the handles. The draw-bar hooks are of peculiar shape. When uncoupled the levers are secured by a rod, peculiarly shaped, carried across the end of the wagon.—*Highly Commended.*

FRED PLATT, Wednesbury.—Improved Coupling.—The couplings consist of two wrought iron arms, made to swing horizontally on a pin going through the end of each, which pin is fixed in a jaw formed on the end of draw-bar. On the under side of each arm near the connecting end a flat bar is connected which reaches under buffer to corner of wagon, and terminates there in a handle, to uncouple with, the couplings connecting themselves on wagons meeting together; they may be also be set so as not to couple on meeting together if required. A flat spring is fixed at the back of each arm to keep coupling in position when not pulling. To uncouple pull the handle, which will be found on either side of wagons near buffer.

S. ROBERTS, Tunbridge Wells.—Improved couplings, automatic in action, perfectly harmless to shunter, instantaneous in coupling and uncoupling.

ENOCH SMITH, Walkden, near Bolton.—Self-Acting Couplings.—Coupling boxes in the centre of buffer plank of each wagon, with drop catch in each, horizontal coupling bar, to work on the top of main draw-bar independently. The coupling bar is propelled out by cogwheel and withdrawn with the same. A rod coupled on each drop catch to lift the catch or catches, the detaching is worked by a lever from the outside of the wagon frame near the centre. Fitted for curve.

JACKSON & BALLANTYNE, Uddingston, N.B.—Appliance for Coupling and Uncoupling Railway Wagons.—To couple—Lift the lower handle, and when the coupling link has been raised sufficiently high to permit of its passing over the hook of the wagon opposite, gently press down the upper handle, at the same time gradually lower the coupling into the hook. The handles being then released the appliance falls into its normal position, quite free from the jerking and oscillation of the coupling while the train is in motion. To uncouple—raise the lower handle and slightly depress the upper. This will bring the "clutch" of the appliance under and in contact with the extreme link of the coupling, indeed, the link actually lies in the "clutch," and while in this position press down the upper handle, and coupling will be removed from the hook.

W. L. EVERIT, New Haven, Conn.—Automatic Car Acting Car Coupler.—It can be converted into a common link and pin attachment when required by raising the pin to its fullest extent and pushing the draw loop back out of the way, and connect the link of the opposing coupler by the centre pin, which cannot be drawn entirely out ; but when raised and tilted back, rests on a little offset, and will remain up till the concussion throws it into place, thus rendering this part also automatic. This coupling is operated by a chain leading from the lever to top of car, and the only hand work required is in pulling this chain to uncouple.

RICHARDSON & GREENWOOD, Harrogate.—Automatic Coupling.—Showing self-acting operative, fly shunting, and slip couplers combined, upon block and spring buffers, with or without screw tighteners.—*Highly Commended.*

JOHN D. CAMM, Todmorden.—The invention is of the nature of a dumb-bell fixed in sockets at the end of each carriage, wagon, or truck, is automatic in action, and can be uncoupled by means of a spring placed in the side of each carriage, wagon, or truck.

THOMAS HUDSON, Darlington.—Apparatus for Coupling and Uncoupling Railway Trucks.—The special advantage claimed for this is, that it takes hold of the first link, and can be applied to all coupling chains varying from 1 inch to $1\frac{1}{2}$ inches in diameter.

OSWALD COULSON, Darlington.—This is adapted for coupling and uncoupling trucks either above or below the buffers, and for uncoupling the side chains. It is so arranged that it meets all the requirements of the various coupling chains now in use in Great Britain and Ireland.—*Highly Commended.*

HERSEE & Co. Buffalo, America.—This is arranged so that it can uncouple from roof or ground, but by pressing down the lever, coupling can be prevented when shunting in goods yards, and by pulling up the chain on the roof the same result is obtained. If by an accident the wagons get off the line the couplings become loose without injury.

ASKEW's Patent Coupler, Cowlairs.—By means of this simple instrument the existing wagon couplings from $1\frac{1}{4}$in. to $1\frac{1}{2}$in. diameter or of greater or less diameters), and safety chain hooks can be coupled or uncoupled more expeditiously than by the use of the hand only.

WATKINS & WILLIAMS, Iowa, America, describe their car coupler as automatic in action, simple in design, and adaptable to all kinds of railway rolling stock.

J. G. SCOTT, Chicontinn, Quebec.—Coupler.—The process of coupling is as follows :—The operator goes to the car standing at rest, lifts the coupling bar sufficiently high to allow the bar to pass over the heads of the pins on the buffer of the moving car, and at the moment of contact drops the bar behind the pins, and the operation is complete. In uncoupling a slight relaxation of tension by backing down from the locomotive, and the bar is lifted over the pins, and falls under the buffers, out of the way.

F. BARNES, Lower Sydenham.—Improved Coupling.—This apparatus is constructed with a conical guide shield, the apex of which is projected rear-wardly in an oblong form

as a neck, and is drilled with three holes. The exterior of the neck has hinged to it a weighted lever, provided with a bevelled projection, and formed at its upper end with a catch. The lever is weighted to keep its projection in the hole, and to keep its catch under a conically topped flange on a vertical rod, which is held in position by a bracket immediately over the slots when the vehicles are disconnected. These brackets project rear-wardly, and form the top, bottom, and sides of the neck, and they are securely kept in position by a plate through which they pass. Each end of the vehicle is fitted thus :—Into one of the shields is placed a connecting bar which is held in position by the drop pin, and as the slotted portion of the connecting bar passes into the neck of the opposite apparatus, the bevelled projection is thrust aside. This releases the drop pin which falls through the holes and the slot in the bar, and effects the desired connection.

F. Barnes, Lower Sydenham.—Coupling Appliance.—To a handle or lever is attached at one end a peculiar forked arrangement so formed that one part is bent to take into the opening in the second link of a chain. The other part is formed so as to enable the end link of the chain to rest thereon, which is effected by giving this portion a waved or zig-zag form. In coupling the forked portion is passed into the second link, and on the waved portion the end link rests. The chain is then raised, and the link resting on the waved portion is dropped into the hook to receive the same, and the wagons are coupled. To uncouple, all that is required is to apply the appliances to the links in like manner, and the same are lifted from the hook.—*Prize Medal.*

R. L. Rylance, Southport.—Automatic Couplers.—Consists of two buffer-shaped boxes to be fixed under the centre of each carriage or wagon, having an aperture in the top part of that end which is joined to the carriage, through which a piece of iron or key passes and locks the coupler. A connecting rod having a slot made in each end is fixed in one of the boxes, and on being pushed against the other box lifts up the key, which immediately falls down again through the slotch, on its passing or being pushed in, and so locks the carriages. This key can be raised at will from either side of the carriage by means of a lever attached to the key-bar, and may be secured in an unlocked position for the purpose of shunting, &c., any length of time.

O. A. Outram, London.—Improved Coupling.—Bring the wagons together and move the lever at the side of the wagon into a horizontal position, when the wagons will be connected. To lock or secure the fastening, push or pull (according to the side of the wagon on which the operator is fixed) the small handle which is just below the coupling lever already mentioned, and the coupling will be securely locked. To uncouple—Move the small handle (which is attached to the locking plate) to the first position, and then press down the coupling lever to the perpendicular position and the wagons are uncoupled. Great simplicity and non-liability to get out of order are claimed for this invention.

RAILWAY SIGNALLING.

(*Continued from page* 271.)

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We have now somewhat exhaustively considered the different systems, ramifications, and extensions of "mechanical interlocking" as an indispensable attribute of safety and dispatch in the working of railway traffic. Of course, we would not infer that the mechanical genius of man is infallible, or that, in some rare instances, through absolute confidence having been placed in appliances provided, accidents have not resulted, which might otherwise have been avoided by common care and intelligence. For example, the reader may perhaps remember the facts of the accident which occurred not long since near Nottingham, owing to some slight derangement of the interlocking apparatus, and by which thirty passengers were more or less seriously injured. From subsequent investigation it was proved that a certain stop or stops of the interlocking frame had failed to engage with certain conflicting levers, the consequence being that the signalman, who relied entirely upon his apparatus for the safe conduct of traffic, was enabled to operate some coalyard siding-points whilst the main line signals were lowered. The immediate cause of the collision was undoubtedly from the failure of the mechanical appliances; but, on the other hand, the signalman in charge was by no means free from blame, for by common attention he should have observed the point lever over on his frame, at the time he was about to lower the main signals. No mechanical contrivances, however perfect, can be considered infallible, although their value cannot be over-estimated, so that the operator in charge should always be taught to exercise no less care and attention than if without such mechanical preventives against blunder.

With such above-mentioned common intelligence and care, the "Interlocking System" is invaluable, and of unparalleled importance in the working of modern railway traffic.

In England and Wales about 21,500 point and signal

levers are thus suitably interlocked in accordance with the requirements of the Board of Trade, representing upwards of 82 per cent. of the total number of such levers in use in this portion of the United Kingdom. Similarly in Scotland, over 3,000 levers are controlled by the interlocking system, or about 64 per cent. of the total number in use; whilst Ireland has only 690 levers, or 38 per cent. of the levers in use, interlocked. Thus we find on the railways of the whole United Kingdom, we have about 25,300 point and signal levers daily controlled by this invaluable system, or about 77 per cent. of all the levers of the kind in use in the country.

As a matter of interest to our younger readers, we will now pass on to consider some of the essential features to be observed in preparing specifications for signal work. As before stated, with the exception of the Midland and London and North-Western railways, it is the usual practice of our railway companies to invite the principal signal engineers and contractors to tender for any signal work of importance, which has generally proved the cheaper and wiser plan, unless such companies have a special and efficient department for executing extensive work with proper despatch. In such cases it is usually the practice to provide the contractors with a specification of certain requirements, dimensions, and materials, &c., to be observed in accordance with the views of the engineer of any particular line. Not many years ago, railway engineers were practically confined to only a very few firms for their signalling and safety appliances (in cases where they did not manufacture themselves), owing to the monopoly of Patent rights, and notions that only certain appliances possessed the required degree of efficiency. Whereas at present the field is comparatively open, and price has become the main desideratum.

In preparing specifications for tenders of first-class signal work, there are many points requiring consideration, *e.g.*, the conditions of the contract; the materials desired to be used; the powers of the company's engineer; time to be occupied for completing the work; payments of accounts; the question of indemnity against existing Patent rights; the appropriation of old materials; details as to signal boxes, signals, and point apparatus; tables of interlocking; painting; the making good of works disturbed by the contractor; the period the contractor will be required to maintain his work in efficient order, and the contractor's liabilities, &c.

For these purposes a ground plan and, in some cases, detail drawings are provided to accompany the specification, while any further information required is usually to be obtained by application to the railway company's engineer. The contractor is generally called upon to quote a "lump sum" for the whole of the works complete, in accordance with the said specification and drawings, while the company's engineer frequently reserves to himself the right to modify, increase, or diminish such works as he may think desirable, without invalidating the contract. The construction of the specification, and the efficiency of the work performed, are matters left to the decision of the company's engineer, under whose supervision the work is carried out. It is usually to be understood that although a specification may not be sufficiently amplified as to afford every detail information, that it is intended to cover all points necessary to the efficient execution and fulfilment of the work in question. The contractor is further considered responsible for any accidents which may arise from his own or his servants' negligence, as for example, through materials or tackle being left so as to interfere with the safe conduct of traffic. Contractors are in some cases required to furnish separate tenders for works to be executed at different stations or sections, so that the company's engineer retains the power to accept or reject certain portions of the tenders.

The contractor is held responsible for the efficiency of the apparatus he may supply. And that the same shall fulfil all necessary requirements of the inspectors of the Board of Trade, should the arrangements fail to pass such approval, the contractor is really required to make good such defect at his own risk and cost. For this purpose, accounts for the work done, are usually paid upon the certificate of the company's engineer, with a small percentage retained until the work is passed by the officers of the Board of Trade, and remained satisfactorily in good working order for about three months after such date.

The materials and workmanship employed, if not specified in detail, are always intended to be of the very best description, and all unsound materials or defective work must be made good by the contractor. In some cases patterns or samples of the same may be inspected at the particular railway company's stores.

The timber used upon the works should be well seasoned Dantzic, Riga, memel or pitch pine, free from large or dead knots, sap or other detrimental imperfections, and no white timber should be allowed on the works. All the timber for fixing cranks, pulleys, roller boxes, stumps, for signal wires, &c., should be creosoted.

The colour, and amount of painting should be specified for both wood and iron work, as also the use of anti-corrosive compositions, tar and varnish, and the number of coats desired to be given.

All signals and their boxes have to be erected in the positions indicated upon the drawings furnished, and care has to be taken that all such structures are "clear of the company's construction gauge," and not less than about 5 ft. from the nearest rail. The heights of the signal posts should also be indicated upon the drawings, and all through should be carried up sufficiently high, and in suitable localities, so as to afford a good unobstructed view for a considerable distance. Yet unnecessary elevations of "Distants, Stops, or Homes" should be avoided, and all starters be placed as near the level of the driver's head as possible. The heights of the signals are commonly read from the formation or rail level to the centre lines of the top arms. The feet of the posts are usually provided

with metal soles and spurs, set in the ground at the required depth, and all underground work is well creosoted or tarred. The signal arms, which may run about 6ft. from extremities to centre lines of the posts, should be bound at their ends with copper bands to prevent splitting, and the two or three indications or positions that the signals will be required to give or occupy, definitely specified.

If the lamps be not supplied by the company, proper information should be given as to the essential requirements *e.g.*, whether for gas or oil, &c., the selection and design being usually left to the company's engineer.

In all cases the back lights should be as small as practically possible (*e.g.* 1¼ ins.), and proper and safe access provided to the lamps by wrought iron ladders and galleries.

All necessary and desired stays, struts, and signal fittings, &c., should be briefly specified, *e.g.*, ⅝ in. arm rods, 10 in. wrought cranks, and 10 in. chain guide pulleys and angle wheels with connections formed in the most direct manner practicable; 5 to 6 ft. of chain to be provided for each chain wheel, and all signal pulls to be formed of 7-stranded galvanized wire of best quality, carried by suitable pullies mounted on creosoted redwood stumps or stakes from say, 25 to 30 feet apart. The junctions of wires are usually formed with thimbles.

The signal gear is to be provided with all necessary compensation screws or devices and counterbalances.

The interlocking apparatus is expected to incorporate all modern improvements essential to the most recent requirements of the Officers of the Board of Trade, and when a price is tendered per lever, it is (unless otherwise stated) intended to include all necessary appendages for the efficient forward and back locking and releasing of the levers and necessary counterbances, &c., in connection therewith.

The rods connected with the point levers for actuating the switches are usually 1¼ ins. in diameter, and weighing about 5 lbs. per yard, exclusive of joints, and are carried over cast-iron rollers about 7ft. apart. All bends in the point-rods should be solid, and connections made by male and female joints rivetted and keyed, and all necessary adjusting screws and compensating levers must be included in the tender.

The cranks for working point connections are almost invariably made of wrought iron; while those for the signals may be cast. All necessary joints, cover boxes, and fixing are to be included.

The timber frames for carrying the cranks should be formed of about 12 in. by 6 in. timber, securely staked to the ground.

Ground discs where required, should be shown and specified, as also their interlocking.

All facing points shewn and specified, have to be provided with locks or bolts, which are generally of Messrs. Saxby and Farmer's latest pattern.

The points and locking apparatus should be operated by two separate levers and connections.

The levers are commonly painted as follows:—

Distant Signal levers	Green.
Other Signal do.	Red.
Point Levers	Black.
Do. locking levers	Blue.
Spare, or levers not in use	White.

The form of proposed tender accompanying the specification to be filled in and returned by the contractors, is usually somewhat of the following nature:—

TENDER

FOR

Signalling work at.....

To the Directors of the.....Railway Co.

GENTLEMEN,

After perusing and examining the accompanying specification and drawings..... hereby agree to provide all materials, plant, labour, &c., and to execute the whole (or part) of the work required to be done, according to the terms and conditions cited in the said specification, and to complete the same within ..... calendar months from ..... acceptance of the contract, to the entire satisfaction of your Engineer and the Board of Trade, for the sum of ....., the said Engineer's decisions to be in all cases considered as final and binding.

Yours, &c.

Signature.....

Address .....

Date.....

(*To be continued.*)

THE CHANNEL TUNNEL.

(*Continued from page* 269.

THE appearance of the long-expected Blue Book on this subject is indeed a welcome event. Containing, as it does, every scrap of information which it was possible to gather from home and foreign records, from newspapers, and from military and engineering authorities, we are now in possession of an exhaustive and authentic history of all the proceedings that have taken place, and of all the leading opinions favourable and adverse to the project. More than this, not only have we the long and argumentative Memorandum of Sir Garnet Wolseley, but

also his views and arguments in the much clearer, because dissected form of evidence given in reply to the Board of Trade Committee, each member of which, it is clear from the questions put, held certain preconceived opinions which he desired specially to elucidate. The volume is portentous, consisting of three hundred and sixty-eight pages, sufficient to induce the intending reader to wish that his days could be prolonged to the length of those of Hilpa and Shalum, in order that he might find time to digest it properly. There is an advantage, it is true, in producing such matters in a complete form, but, considering that the report of the Military Committee, the last really important public paper, was sent in on May 18, it would perhaps have been better to have issued such voluminous documents by instalments, instead of keeping an expectant public on tenter-hooks for five mortal months.

The importance of the book cannot be exaggerated. It will teach many lessons. Not only is the question under consideration weighed with absolute impartiality by the members of the Committees, but the most marked ability is shown by them and the witnesses they interrogated. No one who reads these pages will ever join in the ridiculous cry that our public men are incapable. This observation applies equally to the private gentlemen who were examined, in the course of whose evidence came out proofs of laborious and sustained effort, and utter abnegation, which place not only their business capacity but also their public spirit beyond the reach of suspicion. That the result of all these proceedings is to leave the question in a very grave state cannot be denied, and, it may be convenient to give a brief account of the official proceedings in order that this may be fully understood.

At the close of 1876 the position of affairs was as follows: The French promoters had obtained their concession, subject to certain conditions, and the capital required was to be found, half by the Chemin de fer du Nord, one quarter by the French House of Rothschild, and one quarter by the promoters and their friends. Lord Grosvenor's Company had no concession, but merely the right to experiment at St. Margaret's Bay, and they only issued a prospectus proposing to raise a capital of £80,000 for experiments. This capital, partly owing to commercial depression, was never raised, and the year allowed for the purchase of land having expired in August, 1876, the work remained in abeyance.

In 1880, however, a second English scheme was brought forward, in addition to the original "Channel Tunnel Company." This new scheme was initiated by the Chairman of the South Eastern Railway Company, and was based on the results of experiments made by sinking shafts on the property of that railway company in the neighbourhood of Dover. These experiments, for which the South Eastern Railway Company, under the sanction of an Act of Parliament, had authorized the directors to spend £20,000, were continued during 1881, and at an Extraordinary General Meeting of the South Eastern Railway Company held in London on the 16th June, 1881, the chairman announced to the shareholders that the results showed the possibility of completing an experimental tunnel seven feet in diameter within a period of five years, work being carried on simultaneously from both ends. The report of this meeting having attracted the attention of the Board of Trade, a Departmental Committee was appointed on the 22nd August, 1881:—Mr. Farrer, Chairman, Vice-Admiral Phillimore, and Colonel J. H. Smith, R.E. The documents brought before the Committee comprised a memorandum by Sir Garnet Wolseley, dated 10th December, 1881, and a memorandum by Sir John Adye, dated January, 1882.

Sir Garnet Wolseley urged that no question of such vital importance had ever before come up for the serious consideration of the nation; that there would always be a risk of our end of the tunnel being seized by surprise or by means of treachery, and that its seizure would place England at the mercy of the invader.

Sir John Adye did not consider that any great danger to this country would be created by the completion of a submarine tunnel. It could not be used for the purpose of invasion unless our end of it had been previously seized, and the end could only be seized after a successful invasion by sea. The defence of the tunnel exit was a simple operation, and the destruction of the tunnel, should such be necessary, would be equally so. The precautions to be taken were of a comparatively simple character.

On the 31st January, 1882, Admiral Sir A. Cooper Key, as a Member of the Board of Admiralty, wrote to the First Lord, stating his opinion that the construction of the tunnel would render necessary a vast expenditure in fortifications, or the maintenance of a standing army as large as those of other European nations. Mechanical contrivances for destroying the tunnel could not be relied on. The commercial advantages of the tunnel would be obtained at the expense of our shipping interest. If an enemy obtained possession of the tunnel, a large army might march on London, while our navy looked on as a helpless spectator.

The Committee took evidence as to the rival schemes, but on the 1st February, 1882, the chairman informed the President of the Board of Trade that during the course of the inquiry the effect which such schemes might have on the military defences of the country had assumed great importance, and that the Committee desired to have further military and naval evidence on this subject. In reply, the President of the Board of Trade informed the chairman that as the final decision of a question of such magnitude would not rest with a Departmental Committee, but must be settled on the responsibility of the Government as a whole, he would not prolong the labours of the Committee.

The investigations of Mr. Farrer's Committee being thus brought to a close, the Board of Trade immediately notified to the War Office the circumstances under which

this committee had been dissolved, and forwarded copies of the evidence taken and of other documents brought before the committee, in order that such further enquiry as the Secretary of State for War considered necessary, might be made. It was then decided by the Secretary of State for War, that before the wider military question involved in the Channel Tunnel scheme was submitted to the Government, the opinion of a scientific Committee, composed of both military men and civilians, should be obtained, as to the practicability of effectually closing such a tunnel, if made. On the 23rd February, 1882, the following gentlemen were accordingly appointed by the Secretary of State for War, to carry out this duty :—President: Major-General Sir A. Alison, Bart, K.C.B. Members: C. H. Gregory, Esq., C.E., C.M.G.; Major-General Gallwey, Inspector-General of Fortifications; Colonel Sir John Stokes, K.C.B., R.E., Deputy Adjutant-General, Royal Engineers; Colonel Sir Andrew Clarke, K.C.M.G., C.B. R.E., Commandant of the School of Military Engineering; E. Graves, Esq., Engineer-in-Chief to the General Post Office; Colonel H. J. Alderson, R.A., Assistant-Director of Artillery and Stores, War Office; Colonel V. D. Majendie, C.B., H.M. Chief Inspector of Explosives, Home Office; Professor Abel, C.B., F.R.S., Chemist to the War Department.

The Committee were directed to make a full and exhaustive investigation from a scientific point of view (and without reference to the ulterior question of national expediency) into the practicability of closing effectually a submarine railway tunnel proposed to be constructed between France and England. They were to satisfy themselves whether it was certain, beyond any reasonable doubt that, in the event of war, or apprehended war, the tunnel and its proposed approaches under existing Acts and the Bills then before Parliament, would be rendered absolutely useless to an enemy, and in what manner. A very detailed discussion of the various means to be used was called for, and the Committee were informed that in their recommendations *they should not be influenced by considerations of cost, as the first charge and maintenance of all necessary works would have to be defrayed by the owners of the tunnel.*

Sir Archibald Alison's committee completed their inquiries on the 12th May, 1882. The following are the main features of their report :—

The Committee considered that it was undesirable that the end of the tunnel should be within effective range from the sea, and decided that the following conditions were essential :—The tunnel should not emerge within any fortification, but its exit as well as the air-shafts, pumping apparatus, &c., should be commanded by the advanced works of a fortress.

There should be means of closing the tunnel by a portcullis, and also of discharging irrespirable gases into it.

There should be power to produce a temporary demolition of the land portion of the tunnel by means of mining.

There should be arrangements for a temporary flooding of the tunnel by sluices.

There should be arrangements for a permanent flooding of the tunnel by mines which should open a direct communication between the bottom of the sea and the tunnel.

The mechanical arrangements required for temporary obstruction should be capable of being controlled from different points within the fortifications, and the means of destroying the tunnel should be controlled, not only from the central work of the fortress, but also from one or more distant places, which should have distinct communications with the mines, independent of those of the fortress.

The Committee also considered the two schemes for which Bills are before Parliament, and decided that neither of these schemes, as defined by the Bills, could be recommended, inasmuch as they failed to fulfil some of the conditions mentioned above as being essential.

The Committee concluded by recording their opinion that "it would be presumptuous to place absolute reliance upon even the most comprehensive and complete arrangements which can be devised, with a view of rendering the tunnel absolutely useless to an enemy in every imaginable contingency."

On the report being referred by the Secretary of State for opinion, the Surveyor-General of Ordnance (Sir John Adye) considered that the recommendations of the Committee would amply suffice for the object in view; are sound and practicable, and can be carried out without great cost or difficulty. Nothing in his opinion was more obvious than the facility with which the tunnel could be denied to an enemy, by means which no vigilance on his part could prevent or remove.

The Adjutant-General (Sir Garnet Wolseley) was strengthened in his conviction that the hour when the tunnel was sanctioned would be for England a most disastrous one. He maintained that there could be no stronger proof of the existence of danger than the magnitude and elaborate nature of the precautions recommended by the Committee. The Channel Tunnel proprietors might be of any and every nationality. In spite of all precautions, our end of the tunnel could be seized by a *coup de main*. The improved harbours on the French coast would make a surprise more easy. Surprises during peace were the common-places of history. The tunnel would directly tempt invasion—it would be the most unassailable line of communications in the world. The successful invasion of England, with the tunnel in the enemy's hands, would be the permanent ruin of the country. Neither fortifications nor scientific agencies could be trusted. It would be impossible to keep secret any military arrangements connected with mines. The danger of the tunnel would be an increasing one, because as time went on the precautions would be

neglected. Why should a new danger be added to those which already existed? From the commercial aspect, even a shadow of danger would be a heavy balance against any possible advantages. The liability to panics would be increased.

His Royal Highness the Field-Marshal Commanding in Chief could not too strongly express his satisfaction that the country was in no way committed to any definite engagement either to France or to any body of promoters. There was a large concensus of military opinion, which found expression in the evidence of the Adjutant-General before the Board of Trade Committee, and the statements of the case put forward by that officer had his Royal Highness's entire approval. In the Report of the Committee, the words used must be given their full force, and *a first-class fortress, in the modern acceptation of the term*, meant such a fortress as certainly could not be constructed for less than three millions sterling, and which would require a garrison equal to the great garrisons on the Continent. The whole of the money required for this as well as for the multiplication of methods which the Committee considered it imperative to have for rendering the tunnel impassable, should be paid over to the Treasury before permission was given to begin the tunnel at all. The report of the Committee amounted to an absolute condemnation of every existing proposal for a Channel Tunnel, and it was imperative that if any new or modified schemes were brought forward they should be submitted to the Committee. The Committee admitted that the most elaborate scheme of defence would not give immunity from danger. No reliance could be placed on the electrical communication with distant points unless the wires were tested every few hours. All, therefore, depended on the security of the great fortress, and the adoption of precautionary measures when there was a prospect of war. But as the stoppage of the tunnel would be taken as a sure indication of coming war, an English Cabinet would be unwilling to order it. The majority of wars had commenced before diplomatic relations had been broken off. It was not only the possibility of a rupture with France that had to be considered. Any power at war with France, after taking possession of Belgium, might seize Calais. The only positive security against the danger of the tunnel would be the maintenance of a vast army, entailing probably a compulsory system of universal military service. His Royal Highness's plain duty, on military grounds, was to protest most emphatically against the construction of the tunnel.

Sir Andrew Clarke, one of the members of the committee, issued an independent paper in entire agreement with the views of Sir John Adye, in the course of which he says, "Were I even to accept to the full all that has been urged, on political and general grounds, against the establishment of unbroken lines of communication, I should, nevertheless, hold that the resources of military forethought and science are not so used up but that we could reduce to a minimum, if not obliterate, all possible risk of danger, or even of panic, from the making of a tunnel between the two countries."

Now, it must be confessed, that there is here no appearance of that "concensus of military opinion" alluded to by the Commander in Chief, to whose memorandum, inasmuch as generally it only says ditto to the Adjutant-General, we need not at present more particularly refer. The upshot of the inquiry is that this committee, composed of as eminent and capable gentlemen as could possibly have been got together, being asked a question whose limits were defined with the utmost strictness, have replied categorically indicating the means by which, in the words of Sir Andrew Clarke, its not least distinguished member, "all possible danger can be reduced to a minimum, if not obliterated altogether." The two generals who gave evidence before Mr. Farrer's committee, and whose opinions were asked upon the report of that of Sir Archibald Alison, hold diametrically opposite views. There is no point of agreement between them at all. One says that if you create this tunnel, sooner or later the dream of the great Napoleon will be realized, and "England will be no more." The other just laughs at him. It really says a great deal for the discipline and good feeling that exists amongst the superior officers of the Army that, after such an episode, the heterodox Surveyor General of Ordnance should have been chosen, and consented to act, as chief of the staff in Egypt to the General with whom he so totally disagreed Sir Garnet, who does not scruple to avow his admiration for the military genius of Napoleon, advances the theory that supposing France to be governed by a man of his turn of mind and morality, he might find himself in such a position as to lead him to say to himself, "In order to do something that will turn the attention of the people from internal affairs, or else with a view to obtain supreme power for myself, in order to obtain great notoriety or a great advantage for my country, and being unable to do anything on the German frontier, I am obliged to adopt the only one possible means of effecting these objects, that is, by a sudden descent on England; England being always in an undefended condition, I will attack her without any warning." The method of attack, Sir Garnet explains, would be "by sending through the tunnel itself (which would be the simplest plan) a couple of thousand men who would seize at once the railway stations and all your electrical apparatus, knowing beforehand, as they certainly would know, where every wire was, and every plan that you had devised for the destruction of the tunnel. Or, they might be landed in the harbour itself because I start with the assumption that whenever it is done, it will be done in a state of almost profound peace without any warning whatever." This is what the General says, and all he says, although he occupies thirty-seven folio pages in saying it, and eight pages more with his endorsing evidence. His standpoint is that we are always unprepared, and that nothing would be more

easy than for an unscrupulous foreign ruler to concentrate an army, seize our tunnel and its defences with an advanced body of two thousand men, and re-inforce them comparatively at his leisure, But he admits that this must be done in the "clearest of skies," without one scintilla of warning. There must be no Egyptian or Tunisian question upon the horizon; no cloud, even so big as a man's hand, calculated to arouse the susceptibilities of the foreigner and give him an excuse for invasion; no newspaper article drawing attention, even in the mildest terms, to the selfish attitude of perfidious Albion. Peace must be profound, our relations with all Europe of the most cordial character. There must be absolutely nothing which could in the most distant manner raise our suspicions, nothing that could give us the slightest warning. Yet Sir Garnet tells us in reply to question 247—"I should say that the unstable nature of Governments in France ought to be sufficient warning to us at all times," and, further, that "for any man to attempt the passage of the tunnel with one hundred hostile riflemen at its mouth would be madness." We know General Wolseley to be a good hand at surprises, but venture to doubt how a foreign commander, possessing even *his* genius in this species of warfare, is going to surprise a country which is or ought to be always sufficiently warned, especially when the presence of one hundred defending riflemen would constitute his adventure an act of madness. Besides, how is secrecy to be maintained? The whole continent is at all seasons overrun by British tourists. Would it be possible to mobilize an army of 150,00 men without some of these getting an inkling of what was going on? And how could they be prevented from giving our authorities such notice as would place them completely on their guard? Would this adventurous and unscrupulous successor of the immoral Napoleon cut the telegraph wires, suspend the operations of the Post Office, and prevent all egress from the ports? Either of these acts would immediately expose his purposes and prevent their consummation. But, supposing this difficulty overcome, the advanced body of 2000 men cannot come out of a hole fourteen feet in diameter all at once. Before 200 had emerged, suspicion would be aroused; these would be seized and disarmed, and the Commandant at Dover would have utilized the appliances ready to his hand for temporarily stopping the passage of the tunnel, with the immediate result of drowning, suffocating or blowing up the 1800 invaders who remained therein. What would become of the projector of this notable strategic movement is not difficult to surmise. If not torn to pieces by the Parisian populace to the chorus of "*Nous sommes trahis*," it would be because, having been shrewd enough to foresee its almost certain failure, he had provided himself with an adequate disguise, and fled in time to save his miserable life—to linger out the remnant of his days, too abject a thing for ridicule, and immeasurably beneath contempt.

Sir Garnet may congratulate himself upon having more successfully matured his plans at Tel-el-Kebir than he did his ideas upon the Channel Tunnel. In this he affords another illustration of the fact that the sagacity which makes a man victorious in his own vocation is altogether at fault when applied to extraneous matters, which, from the peculiar bent of its possessor's intellect, he can only look at from one point of view, and that the wrong one. He says that it is not at all sufficiently proved that the commercial advantages likely to accrue from the successful achievement of the project will compensate for the increased danger thereby created. But it *is* proved, and is admitted by all who have given to this side of the question the same attention that Sir Garnet has paid to its military aspect. As regards the danger, as good, as brave, as able, and more scientific soldiers than Sir Garnet have affirmed that there is no danger at all, because a danger that can be nullified does not exist. One thing has been made abundantly apparent in the course of this enquiry. It is agreed that increased means of communication between countries add to facilities for invasion. Steam, it appears, has removed a formidable barrier to the conquest of England, only since its introduction the great conqueror, with impossible ideas, whom General Wolseley has evolved from his inner consciousness, has, fortunately for us, not yet made his appearance in the flesh. Mr. Farrer, in his questions, dwelt forcibly upon the improvement in international feeling, and the tendency that the extension of trade and personal intercourse have, so far as they go, to prevent war. Sir Garnet's reading of history does not agree with that. He finds that there have been more wars since those communications have been extended than there were twenty years back. This is not the way to read history, and the views of those who thus read it are of no value at all. Means of intercommunication have been constantly increasing and improving since the days of the Vikings, or, if you will, since the times of the Phœnicians, and there is now less war than ever. If you are going to take any isolated period of twenty years as an illustration of the material progress or bloodthirstiness of mankind, you can prove anything you choose; but Sir Garnet Wolseley has proved only that Captain Sword is sometimes disastrously unsuccessful in the *role* of Captain Pen.

The evidence of Sir John Adye contains some of the best reading in the language. He had visited the tunnel and knew all about it. He had no prejudices, but exceedingly well developed convictions. He said that 2,000 or 5000 men might arrive by some extraordinary means, "but that would not give them possession of the forts of Dover. They would be completely in your power, without food or ammunition, and the first thing you would do would be to destroy by some simple method the means of communication behind them, and take them all prisoners." Sir John then generally indicates the methods, and how they could be multiplied to any extent, and shows that it would be impossible for an enemy, even if thoroughly acquainted with their whereabouts, to seek for and destroy them all before some at least of them had been sprung by the defenders. When asked whether, if in command

of troops, he would undertake the invasion of England through the tunnel, he replied that it was the last thing he should think of, because he should consider it certain to end in ridiculous failure. He further said that the danger of the tunnel to this country would be very small ; that its defence would cost very little, and continued, " I go even further, and say that even were it an additional danger, I think we should not be justified in putting a veto on a rapid means of communication with France "—" and that the attention of military men should be turned to the means which should be adopted for nullifying those dangers in time of war." Here is the whole question in a nut-shell from a large-minded man. If the tunnel is necessary for the benefit of mankind, make it, and leave it to those whose business it is to devise means for its security. But that, continued the witness, was not a difficult question. No great knowledge of war was required for so simple a problem. Plenty of civilians would devise means for nullifying the danger. Any man of common sense could do it. It is refreshing in the midst of an avalanche of spurious patriotism to find a soldier who thoroughly understands the spirit of his age, who recognizes that his business is not to stop peaceful progress, but to be ever watchful and prepared to defend the people engaged in it and the places where it is carried on.

It seems to us that the military opposition to the Tunnel has failed. It will be impossible for those who are finally responsible to the nation to ignore the views of Sir John Adye and Sir Andrew Clarke, and the verdict of the military committee. These are all in absolute accord, and the latter, in referring to the presumption of placing absolute reliance on any means of defence, however comprehensive, are only guarding themselves as sensible men against the chances of human fallibility. The question must, we imagine, eventually resolve itself into one of hard cash. Engineers have decided that, given the continuance of the grey chalk, the construction of the tunnel is easy. Scientific soldiers have staked their reputation upon the assertion that, if made, it is easily defended. Commercial men will now ask if it will pay ? The Duke of Cambridge demands the construction of a first-class fortress, to cost three millions of money, and requires that this amount, together with the further sum necessary for the multiplication of methods to render it impassable, should be paid over to the Treasury before permission is given to begin the tunnel at all. This is a stupendous proposition, calculated to take away the breath of the average financier, but exhibiting on examination only the impractical vapouring of an amiable and illustrious gentleman, who certainly cannot know as much about the matter as the Surveyor-General of Ordnance. If the duke had power to issue a decree to the effect he advises, there would be an end of the tunnel, for we have it on the authority of Mr. J. S. Forbes—given, it is true, seven years ago—that Sir John Hawkshaw's extreme limit of cost of construction was ten millions of money, and that he, Mr. Forbes, had never been able to produce any traffic estimates that did not fall far short of 5 per cent. upon such an amount. Since that period, however, other eminent authorities have reduced the probable cost to five millions, a capital upon which a decent and increasing dividend would doubtless be earned. But if the first three, four, or five millions subscribed are to be handed over to the Treasury, we do not think that even Sir Edward Watkin, with all his sanguine views of finance, knows where to find the necessary subscribers. And we are not at all sure that this eminent gentleman is not indirectly responsible for His Royal Highness's preposterous suggestion. When examined before Sir Archibald Alison's committee, on March 28 last, Sir Edward, in the course of a most able, exhaustive and instructive detail of the scheme, pledged himself on behalf of those he represented, to the construction, at an indicated spot, of a large concrete fort of about 5000 yards superficial area, which would take about half a million tons of concrete. We cannot help thinking that this rash undertaking gave to the military authorities the first idea of this summary method of stopping the affair altogether. It is impossible to conceive that so wild a notion could otherwise have entered their heads. Enthusiasm is an excellent and vaulting thing, but, like ambition, must not o'erleap itself. The public is immeasurably indebted to Sir Edward Watkin for his self-sacrificing labours in this project, but we very much fear that, if it should unhappily be buried, he will see cause to reproach himself with having unwittingly worked at the digging of its grave.

That grave, however, we hope will never be dug. Public necessity survives the antipathies of prejudiced officials, and we repeat our statement in a former article—these are days in which what is necessary must be done. Why an ever-victorious General should man a rush against a magnificently useful enterprise we cannot conceive, unless it is that continued success begets a fear of reverse. Prince Bismarck, when complimented upon the results of his policy, is credited with having replied, " Yes, and I feel that I shall end with a great mistake." Let us hope that Sir Garnet Wolseley will retrieve this, the only error we know him to have made, and that he will not make the great mistake of denying to those who pursue the paths of peace triumphs as exalting as, if less brilliant than, those which it has been his fortune to achieve in war.

COLONEL BEAUMONT'S BORING MACHINE.

THE following description of this machine, for which we are indebted to the *Réuve Générale des Chenins de Fer*, is a nearly literal reproduction of a part of a paper read at the Academie des Sciences by MM. Daubrée and Raoul Duval, upon the Preparatory Works of the Channel Tunnel. The drawing is taken from a photograph which the Société de Construction des Batignoles has kindly furnished of the machine which they constructed and worked at the Sangatte dockyard, in one of the borings projected by the French Channel Tunnel Association.

Instead of boring by blasting, as in the Mont Cenis and St. Gothard tunnels, Colonel Beaumont's machine gouges out at one revolution a perfectly cylindrical hole 7 feet in diameter, in precisely the same manner as an immense centre-drill. The nature of the strata through which the submarine tunnel passes, by reason of its homogeneity and comparative softness, allows the work of boring to be conducted in this manner. Already on the English side the chalk has been pierced to a distance of about 2,000 yards with a Beaumont machine. The machine (illustrated at Plate CLXXI.), constructed in France, has various improvements, which it is hoped will still further increase its utility, which has already proved so satisfactory in England.

The tool of the Beaumont machine is in the shape of a T of which the cross part carries a series of cutters fixed like the heel-tool of a lathe or planing machine; these cutters, by the revolution of the cross-piece, tear off the surface of the chalk. The length of the cross-piece is equal to the diameter of the hole to be bored. The machine consists of two parts; first, the frame, which is at rest while the machine works; second, the boring machine and motor, which advance gradually upon the frame during the operation by means of an arrangement to be presently described. When this second part has arrived at the end of its travel it can be fixed, while the frame advances in its turn over the ground already travelled by the machinery, so as to place the two parts in the initial positions which they had at the commencement of the operation.

The frame is formed in the segment of a circle, of strong plates and angle irons, nearly equal in diameter to that of the hole to be bored, and rests with a little play upon the lower part of the hole pierced by the machine. This frame is provided with sliding surfaces upon which the machinery can advance or recede. The trunk of the T shaped tool is formed of steel and very strong. It receives its rotary motion from the axle of the engine through a series of toothed wheels which gradually reduce the speed. This engine has two cylinders, and is driven by air compressed by Professor Collaton's apparatus to an effective pressure of two atmospheres. The rotary motion of the tool box is accompanied, as before-mentioned, by a forward motion, and which is produced by hydraulic pressure; for this purpose the end of the long steel shaft is connected with the piston of a double acting hydraulic ram fixed to the frame. The water pressure is obtained by means of a small pump worked from the engine, and this, acting upon one of the faces of the hydraulic piston, keeps the cutters in their revolution against the face of the chalk and carries the shaft and machinery forward upon the sliding surfaces attached to the frame. The débris is collected in spaces behind the cutters in the tool box, which in its revolution sends it out of the funnel at the centre of the shaft into an endless chain of buckets, which carry it to the rear of the machine and empty it into wagons placed for that purpose. As soon as the tool has travelled about $4\frac{1}{2}$ feet the engine is stopped. The whole of the machinery is then raised by a system of screw-jacks in front and rear to the height of about one inch. The compressed air is now admitted upon one of the faces of the hydraulic piston, so that by the action of the pump upon the other face, the frame (which by the raising of the machinery is suspended upon it) slides beneath it until it attains the position it occupied with respect to the other before the commencement of the operations. The screw-jacks, are then released and the apparatus is ready for a further advance. The work of moving the lower frame is very simple, and takes but a few minutes.

The pressure of the air is calculated to give to the engine-shaft a speed of 100 revolutions per minute, which is reduced for the tool to $1\frac{1}{2}$ revolutions; the hydraulic apparatus gives an advance of about 1 inch per minute, according to the hardness of the strata where the boring is taking place. By taking into consideration the time spent in fixing the machine at the end of each travel the rate of advance under these conditions will be an average of $3\frac{1}{4}$ feet per hour, which is a very good result.

The machine working on the English side, which is less perfect than the above, advances at the rate of 590 feet in 24 hours.

NOTE.—John Wilkes, Mapplebeck & Co., Patent Brass Works, Abberley Street, Birmingham, have received the highest award (silver medal) at the Naval Exhibition, Tynemouth, for solid drawn brass marine condenser and locomotive tubes.

LONG SPAN BRIDGES AND VIADUCTS, IN IRON, STONE, BRICK, AND TIMBER.

(*Continued from page* 263.)

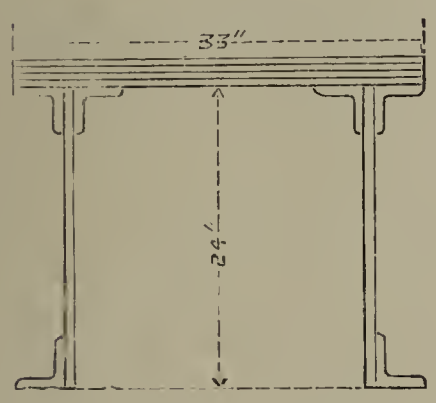
WE must now consider the effect of the load carried on top or bottom flanges of triangular girders between the points of connection with the diagonal bars. The top flange will be first treated.

It is to be assumed that the top flange carries the cross girders placed, say, four feet apart, the connections of the flange with the diagonals being, say, 20 feet apart.

The modification of strain brought about by the *bending action* of the load upon the flange will lead rather to a corresponding modification of form of cross section, than to the introduction of additional material. It will be observed that this is a point particularly affecting "long span" bridges, for in shorter spans the joints will occur sufficiently near together to suit the spacing of the cross girders.

In the first place, some suitable section must be taken as an example. Let it be of the form shown in Fig. 18, the girder being assumed as 200 feet span for our present purpose, and carrying a total load of 3 tons per lineal foot, of which the girder itself weighs one ton per foot,—let the depth be 20 feet, then the central strain will be (by the formula for moments),

FIG. 18



$$=\frac{w\times l^2}{8\times d}=\frac{3\times 200^2}{8\times 20}=750 \text{ tons, and } \frac{750}{5}=150 \text{ sq. in. sectional}$$

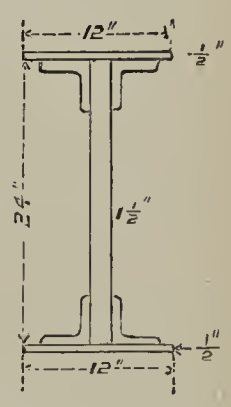
area. This section will be given as shown in Fig. 18, by using angle irons 4 in. × 4 in. × $\frac{3}{4}$ in. thick rolled full, so as to give a section of 6 sq. in. per angle iron and weigh 20 lbs. per foot, the side plates to be 24 in. wide and 1 in. thick each, and the top plates, four in number, each 33 in. wide and $\frac{1}{2}$ in. thick. This gives six angle irons at 6 sq. in. = 36 sq. in.; four plates 33 in. × $\frac{1}{2}$ in. = 66 sq. in.; two plates 24 in. × 1 in. = 48 sq. in., and 36 + 66 + 48 = 150 sq. in. If, then, there were none but the direct compressive strain normal to the girder, regarded as a triangular girder the section shown would give all that is required. Let us, however, see the effect of the bending strain upon it.

Examining the case as that of a girder affected by transverse strain only, we have, taking two tons per lineal foot of the above load and 525 lbs. additional for the weight of the flange dealt with, a total load of 2.234 tons per lineal foot, the span is 20 feet, and effective depth 2 feet, hence the bending moment at the centre will be,

$$M=\frac{w\times l^2}{8}=\frac{2\cdot 234\times \overline{20}^2}{8}=111\cdot 7 \text{ foot tons.}$$

The whole section must in this case be taken into consideration. Now, assuming it to be symmetrical about a horizontal axis (neglecting for the time being the rivets in the bottom flange) the form and dimensions necessary will be furnished by the section shown at Fig. 19. The angle irons are 4 in. × 4 in. × $\frac{3}{4}$ in. Then by the ordinary formula for the moment of resistance we have,

FIG. 19



$$M=\frac{S}{6}\left\{bd^2-(b'd'^2+b''d''^2+b'''d'''^2)\right\}=\frac{5}{6}\left\{12\times\overline{25}^2\right.$$

$$\left.-(2\cdot 5\times\overline{24}^2+8\times\overline{22\cdot 5}^2+1\cdot 5\times\overline{16}^2)\right\}=1355 \text{ in.}$$

tons = 112·9 foot tons, which is as near as we can expect practically to approach the given moment 111.7 foot tons; in fact the excess is only one per cent.

Now, suppose that in addition to the strains in compression and tension thus brought upon the element in question, there comes upon it a direct strain wholly compressive equal in intensity to five tons per sectional square inch all over the section.

The strains due to the bending effort vary from 5 tons per sectional sq. in. on the outside fibres to nothing at the neutral axis or centre of gravity of the section.

From this it is evident that the strain on the lowest fibres will be exactly destroyed, and thence compressive strain will commence from nothing, and increase as the point in the section rises, until at the top, the compressive strains being added together, the compression on the outside fibre becomes 10 tons per sectional square inch, assuming the compressive force to act symmetrically about a line at mid-height of the section. If then the compression joints are so arranged as to bring the strain on in this position, it is evident that the sectional area of the lower half should be taken away and added to that of the upper, so as to make the upper half of the section (Fig. 18) exceed its lower half in area by a quantity equal to the total area of the outside fibres of the section at Fig. 19, and a proportion of all other fibres, diminishing in proportion as we approach the centre.

Practically we may take the excess for the top of the

section thus:—The whole of the flange plates, 12 sq. in.; half the web, 18 sq. in.; all the horizontal limbs of the angle irons, 12 sq. in. The centres of the vertical limbs of the angle irons are 10 in. from the centre of section, hence $\frac{5}{6}$ of their areas, or 10 in., will be the quantity to be taken; this will make a total of $12 + 18 + 12 + 10 = 52$ sq. in. As all the tension is in the result eliminated, there will be no need to make any allowance for rivet holes. It will now be seen that in the arrangement shown in Fig. 18 there is some excess of area in the top of the element, and this will have to be rectified by removing some to the bottom, or by making the line of compression from the diagonals lie above the middle of the flange.

The centre line of the element is 13 in. from the bottom; hence the area below it, as shown, is $2 \times 13 + 2 \times 8 \times \frac{3}{4} = 26 + 12 = 38$ sq. in. This deducted from the total area leaves for the upper part $150 - 38 = 112$ sq. in., showing an excess of $112 - 38 = 74$ sq. in., instead of 52, as required. We, therefore, must take 11 sq. in. from the top and add them to the bottom of the section, which may be done by making the side plates thicker by $\frac{7}{16}$ of an inch, and taking a corresponding area off the top plates. As to whether the excess goes in the vertical or horizontal plates does not matter, as we have allowed for their relative values in determining the excess of area to be used on the upper side of the central line.

In dealing with a loaded bottom flange for distribution of plates in the section, the course to be pursued is exactly analogous to that just explained; but, as the normal direct strain on the bottom flange is *tensile*, it will be the *bottom part* of the section which must have the greater sectional area, and it will be found that thus the top and bottom flanges of the main girder can be made symmetrical about its centre as to general form and arrangement.

It may here be mentioned that as the bending strain will be the same on every length of flange, the *actual amount* of excess of sectional area to be given to one side of the section will be the same throughout the length of the girder, and will not be affected by the varying areas of the flanges, its determination being based upon the supposition that the strains *per sectional square inch* are as nearly constant as practicable throughout the girder.

We have dealt somewhat minutely with this matter of bending strain on members subject to other stresses, as, important though it is, it does not, so far as we know, seem to have received that amount of consideration which it certainly calls for.

We will now take the next example of a long span bridge, having the same leading dimensions as before, but the form will be that of a *tied arch*.

It is advisable here to caution our younger readers against confounding a *tied arch* with a *bowstring girder*, for absurd as such a mistake undoubtedly is, yet it has to our knowledge been some times fallen into even by some who professed to know something about bridges. The difference then is this, in the bow string girder a web of ties and struts, designed as such, is used, the arched part, which should be straight from joint to joint, being a compression member determined as that of other analogous trussed girders; but the tied arch is an arch tied at its extremities by a horizontal member. The roadway is generally carried by vertical suspension members, between which are diagonal ties to distribute the load and reduce its tendency to distort the arch. The lower ends of the vertical suspension members will be attached to the main tie.

A little reflection will show that the main tie of such an arch should be made straight and *not cambered*. If it be cambered, then it follows that when a load comes upon the structure it will cause deflection and *spread the tie* in straightening it, and until it becomes straight it is not doing its duty in holding in the ends of the arch; whereas, if the tie be correctly made, on the load coming into action it will be deflected, and immediately pull upon the ends of the arch, and so resist its spreading, thus reducing its distortion to a mimimum. It is a fact that several tied arches have been made with camber, but this has no doubt arisen from that ignorance that comfounds these structures with girders.

As in the previous example, we shall take dead load as 1.69 tons per lineal foot per gider, and the moving load as 1.5 tons per lineal foot.

The rise or versine of the arch will be assumed as 30 feet, the thrust then at the crown of the arch will be by the ordinary formula;

$$\frac{w.l^2}{8.v} = \frac{3{\cdot}19 \times \overline{300}^2}{8 \times 30} = 1196.25 \text{ tons.}$$

The thrust at the haunches will be:—

$$\sqrt{(1196{\cdot}25)^2 + \left(\frac{w.l}{2}\right)^2} = \sqrt{(1196.25)^2 + (478{\cdot}5)^2} =$$

1288·32 tons. In order to get at the weight, the arithmetical mean of these will be sufficient, it is 1242· tons, dropping the decimals, and this will correspond to a sectional area of $\frac{1242}{5} = 248{\cdot}5$ sq. in. We must now find the length of the arch measured along its centre line. The effective span or chord being 300 feet, and versine 30 feet, its radius will be $\frac{(300)^2}{8 \times 30} \times \frac{30}{2} = 390$ feet, hence the sine of half the arc over which the arch extends, $= \frac{150}{390} = 0{\cdot}38461$, which (as found from a table of sines) corresponds to an arc of 22° 37′, the whole arc being equal to 45° 14′, which gives for the length of the arch:—$\frac{390 \times 3{\cdot}1416 \times 45^\circ\ 14'}{180^\circ} = 307{\cdot}9$ feet, say 308 feet. The weight then of the arch will be, $308 \times 248{\cdot}5 \times 3{\cdot}33 = 255{,}126$ lbs. $= 113{\cdot}8$ tons. The horizontal tie will be subject to the same amount of stress as is the arch at its crown, and we must allow 25 per cent. for rivet holes, hence the nett area would be $\frac{1196{\cdot}25}{4} = 299$ sq. in, corresponding to a weight greater than that of the arch itself, hence we have,

without going any further, already exceeded the weight found for the triangular girder, hence as a matter of economy we should not adopt the tied arch. Plate girders for long spans are now out of date, although their use in the early days of iron bridge engineering may be quite excusable in such structures as the Britannia and Conway Tubular Bridges, examples which no one would now think of following.

Having arrived at the conclusion that for single spans, the triangular system of construction is the right one to adopt, it becomes advisable to enter more fully into the details of execution.

The method of making the joints must always be a matter of vital importance, and this is, moreover, a point which cannot be said to be positively settled.

Take, for instance, the connection of the diagonal bars with the flanges, should pins or rivets be used for this purpose? Experience has shown that pins wear loose, the extent to which this occurs will depend in great measure upon the bearing surface exposed.

Looking at the matter scientifically it would seem that the pin connection is accurate in principle. When a load comes upon a triangular girder, and deflects it from its normal shape, there must necessarily be an alteration in the angles made by its different elements at their junctions, and if these joints be rigidly rivetted up, there will ensue some cross bending in the struts and ties, whereas if they are free to revolve about the centre of the joint, direct strains only will be brought upon them. Assuming that the struts are vertical and at right angles to the flanges, when the structure is unloaded, it must necessarily ensue, upon a load coming upon the girder, that the top flange being shortened, the tops of the struts will be brought closer together, and the bottom flange being extended, the bottoms of those struts will be drawn further apart, and taking any pair of contiguous struts they will no longer be parallel, but the angles at the bottom will have become less, and those at the top greater than right angles on the sides of the struts nearest together; and again, if rivetted joints are used, the rivets will be closed together in one flange, or opened apart in the other, and thus put a lateral strain on the struts at right angles to their length, and so bring a new strain into action besides that which the strut is ordinarily designed to sustain.

On the other hand, however, it is known that a column or strut fixed at the end is much stronger than one on a movable joint, hence here again there are two evils to choose from.

The curvature of the girder in deflecting, will either totally or in part compensate for the alteration of angle between the struts and flanges, for if they stand, after deflection, at right angles to a tangent to the surface of the girders as deflected, no wrenching moment comes upon them, but for such a length as they are solidly rivetted to the flanges we cannot prevent their partaking of the compression and extention of those flanges respectively. If the struts are held by *a single row of rivets*, then the length of connection with the flanges disappears, and the strain alluded to does not come into play.

If the pin is used instead of rivets, let us consider the points to be noticed in applying it. Firstly as to the matter of play, the pin must be loose enough to enter the pin holes, but it must not be loose enough to allow of any rattle or jar when a load passes over the girder; again, if the bars carried on a pin are to be allowed to adjust themselves to varying angles, they must be free to oscillate on the pin, otherwise it will suffer a torsional strain. We know that a turned pin may be made so nearly to fit a bored hole that although it will not enter it when dry, yet after being oiled it may be introduced, well that seems about the sort of fit indicated in the case under consideration, but such niceties of construction are hardly to be obtained from girder makers, especially when, in order to obtain work they are compelled to cut down the price to the lowest figure, hence if pins are used every contingency must be noted and allowed for,—such as deficient bearing surface from want of truth in the bored work; possible torsion from the pin fixing in two or more plates; bending by reason of the plates not being in close contact; and the ordinary shearing force.

There is not the slightest question that the various parts to be joined by a pin should, having been first approximately bored out to nearly finished dimensions, be put in position as intended to be finished, and then bored accurately right through at one cut. The pin at one end is to be slightly tapered to allow of its entering, but when passed right home the whole length upon which the bearing is taken should be cylindrical. To make the pins taper upon their entire length is one way of approaching a fit, but if this is done it is almost certain that in erection they will be drawn so tightly up as to be certain to jam, and thus lead to torsional strains. There is also to be considered the pressure passing through the pin from one side to the other, being a proportional part of that upon the flange (this refers only to the flange in compression) passing from the pier side of the pin towards the centre of the girder.

It will be seen from the foregoing remarks that there is really a collection of strains of all kinds upon a joint pin, and these all require including in the calculation, and the pin making strong enough to carry any or all of them. Torsion being a shearing strain must be added to the direct shearing strain to find the proper area, that is to say the sectional area provided must be sufficient to resist both the strains.

In order to avoid the possibility of the pins setting, there is a great temptation to allow play in the pin holes, greater than is necessary, the fact that constant jarring and vibration of iron renders it crystalline and brittle being lost sight of, thus it might be thought that by keeping the struts and ties so proportioned as to throw the pin a little out of centre and preserve a steady bearing against one side of the hole a little clearance may be allowed without danger, but it will

be found that wherever there is a clearance a rattle will accompany the passage of a load.

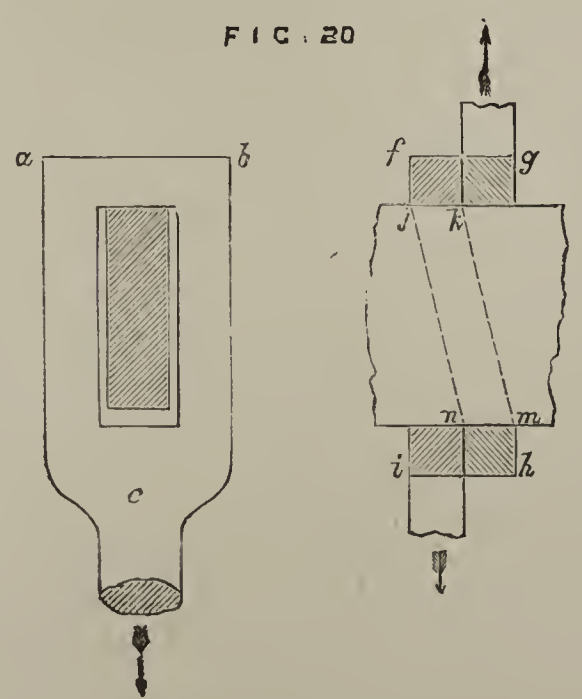
The question of compression of the pin must also receive attention, and it will be observed in going into this matter that it is a good example of how many points must be studied, if we wish to know what we really are doing with our material.

To the beginner fresh from school or college it may seem a simple thing, aided by a note-book of formulæ, or the resources of a well-stored and prompt memory, to sit down and *calculate the strains* on an iron bridge or other structure, and very many there are who in the conceit of their innocent ignorance will, with all honesty of belief be it borne in mind, unhesitatingly assert that they *can* design and detail work; but those who are studious, and continue to work honestly, will soon find that there are many more things in this connection than are comprised in their budding philosophy.

If we wish to keep right we must never lose sight of the fact that every change in the conditions of equilibrium is accompanied by molecular movement; static force, in fact, is only static while its intensity is constant, and thus there are elements of structures which can never be equally strained throughout any given section. To return to the pin under pressure tending to shear it, the calculation commonly taken assumes that the whole sectional area comes uniformly into action in offering its resistance to shearing, but this cannot be absolutely the case; for, if it be large enough, it may actually commence to cut on one side before the strain has reached the central parts with sufficient intensity to sever them, our safeguard against this destruction in detail of the work must be found in keeping sufficiently within the limits of elasticity to render the difference of pressure referred to as small as possible.

It will be seen that the pressure must be equal on diametrically opposite sides of the pin, from which it will diminish towards the centre, and as only that amount of pressure can pass onwards which corresponds to the amount of compression of the material between the outside where

FIG. 20



the force is applied, and any elemental area referred to. From this it appears that by increasing the size of a pin we do not increase the resistance to shearing in exact proportion to the square of the diameter if we keep to the proportions generally obtainable. For simplicity of form let us take the case of a cotter, one section of which is shown at Fig. 20. Let *abc* represent a stirrup carried on a cotter, shown in section shaded, the force acting in the direction of the arrow; let the shaded section be one inch wide and four inches long, then, according to the ordinary mode of calculating, its working load will be 4 ins. × 5 tons per in. = 20 tons.

The first inch down or up from either edge should take 5 tons strain up, leaving 15 tons to pass on to the remaining section; hence the compression of that first inch in a direction parallel to the section submitted to shearing should be that due to 15 tons direct load, and at the second inch the compression should correspond to 10 tons strain, and so on. In order to obtain uniformity in this matter it is evident that the transmitting section should diminish as we approach the centre. If we view the joint in another direction, as shown at *fi*, *gh*, which are sections of the stirrups connected by the cotter, the force being applied in the direction of the arrows, the boundaries of the cotter, as theoretically determined, are indicated by the dotted lines *jn* and *km*, and this at once suggests the idea of the material between the lines *jk*, *nm*, acting as a strut; hence the thickness *jk nm* must be determined on this supposition. In the present case let us ascertain what this thickness should be.

Gordon's formula for the breaking strength of solid wrought iron pillars square in section is, $B.W = \frac{16}{1 + \frac{r^2}{3000}}$

where BW=breaking weight in tons, and r the ratio of the least side to the length. In our example, the length being 4 inches, and thickness one inch, $r=4$ and:—

$B.W = \frac{16}{1 + \frac{16}{3000}} = \frac{16}{1{\cdot}005} = 15{\cdot}92$ tons, and this divided by the factor of safety is, $\frac{15{\cdot}92}{4{\cdot}4} = 3{\cdot}62$ tons per square inch, hence, as the cotter is one inch thick, the 4.4 width of stirrup *jk* or *nm* will be $\frac{20}{3{\cdot}62} = 5{\cdot}52$ inches. Here it would be better to make the cotter more square in shape were we actually adopting it in a practical case.

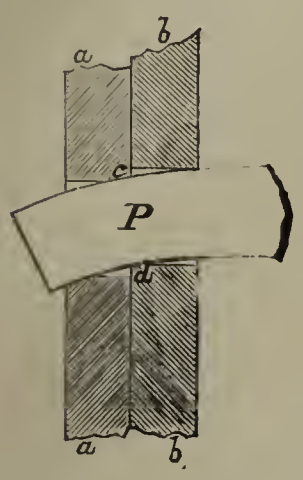
As we proceed, we approach an analysis of the actual nature of this class of strains often hastily disposed of as shearing strains simply.

If there is to be actual shearing in the event of rupture it will be found that a dividing or cutting edge must be present, and this is always carefully avoided, (it is usual in specifying drilled rivet holes to stipulate that the sharp arises round the drilled holes shall be taken off), the

result is, as will be seen by inspecting iron so broken, that it has been *torn asunder*, not sheared off; if this be the case, then it follows that the strain resolves itself into a longitudinal one, but the alteration of intensity accompanying this resolution must be inquired into.

There is another point we must refer to, as it bears upon the question of the pin *having room* to bend as a cantilever. However closely the pinholes may embrace the pin when no strain is in action; directly the strain comes on, those pin holes will elongate as to give room for bending, as shown in the exaggerated section at Fig. 21. *P* is the pin connecting bars or plate *aa, bb*.

FIG. 21



Now, the edges of the plates being of material as soft (and often softer, the pins being frequently made of steel) as the pins, the edges *c* and *d* will be compressed so as to lose all character as cutting edges, and the pin will be deflected as shown.

The pin will now evidently be bent and act as a cantilever, but we must ascertain the virtual length of this cantilever. We think that taking *a a* to be the thinner plate, its thickness should be taken as the effective length of the cantilever, the centre of application of force being in its centre, and the centre of the resistance in the plate *bb* being taken in the same proportion from the plane of contact *cd*, to which distance we may reasonably expect the plate *bb* to yield. There is no doubt that, theoretically, this is correct, if it be assumed that each lamina of metal bring its fair share of strain or load upon the pin, for then there will be also the same number (or area rather) of lamina required in the plate *bb* to receive and sustain the strain as there are in the plate *aa* to transmit it. It is, moreover, in this distribution of strain over the various lamina constituting the plates that we get rid of the shearing action; for in cutting with shears made for the purpose, the effect is obtained by concentrating the force on a very narrow edge, the sharper that edge, the greater the intensity tending to crush a layer of molecules from its position, or in fact we may say a line of molecules, for from the sloping arrangement of the edge of a shear it acts only on one point at a time, its action is progressive, and it destroys an indefinitely thin stratum of material progressively. We may conclude, then, that by allowing a suitable bearing area and proper proportions for the pins, we may altogether abolish the shearing strain upon pins and bolts, having in its place a bending moment.

(*To be continued.*)

INDUSTRIAL EXHIBITION.

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MOST of our readers are aware that the London and South Western Railway Company are the possessors of the ancient ducal mansion of Brunswick, situated at the Vauxhall end of the Walworth Road. Thirty-five years ago the London and South Western Institute and Club was here established under circumstances of considerable promise. The early hopes of the promoters, however, were not permanently fulfilled, and, after a chequered career of thirty-one years, the directors, finding its condition very unsatisfactory, and that there were only forty-one members on the books, contemplated not only withdrawing the generous subsidy they had hitherto contributed, but also closing the institution, and devoting Brunswick House to other purposes. The more public spirited members of the South Western staff heard these tidings with much regret, and determined that the institute should not die without at least an attempt to avert its dissolution. A Provisional Committee was formed with Mr. Fowler, then of the carriage department, Clapham Junction, but now of Nine Elms, as chairman, and Mr. Bennett as secretary. These gentlemen having performed the necessary preliminary work, handed over, in March, 1880, the reins to a permanent committee, with Mr. W. H. Goffe, of the general manager's department, as chairman and Mr. J. E. Hawkins, of the goods superintendent's department, Nine Elms, as deputy chairman. Before the close of the year this energetic committee had succeeded in increasing the number of members from forty-one to si hundred, and the directors were so well satisfied with the new state of affairs that, instead of closing the house and withdrawing their subsidy, they took an increased interest in the institution, and through the kindly intervention of Mr. Wyndham Portal, deputy chairman, carried out various additions and improvements. Every effort has been made to make the institution attractive; a grand piano, two billiard tables, and a bagatelle board, having been purchased, the number of books largely increased and the rooms refurnished throughout. Finally, to render it still more worthy of support, it was determined early in the present year to hold an Industrial and Fine Art Collection, the proceeds of which would be devoted to augmenting the benefits it already confers.

The special Exhibition Committee consisted of Chairman, Mr. J. E. Hawkins, superintendent's office, Nine Elms; Vice-chairman, Mr. A. W. Summerley, carriage department, Nine Elms; Hon. secretary, H. Taman, Esq., assistant secretary of the line; Hon. treasurer, W. Beattie, Esq., assistant locomotive superintendent of line;

Messrs. T. Clarkson, H. Edwards, C. McDonald, T. Rylands, G. Scott, and J. Wright, carriage department. Messrs. J. Stephens, J. Chadwick, P. McCullough, G. Scorer, and W. Tofield, locomotive department, and Mr. Edgar E. Smith, secretary. The result of the labours of this Committee was formally opened on the 23rd ult., by the Lord Mayor and Sheriffs, and consists of 855 Exhibits, divided into 38 classes, all of them constructed by persons belonging to the working classes, besides a Loan Exhibition of high interest and value, the list of articles contained in which occupies no less than fourteen pages of the excellently compiled and lucid catalogue. Such success requires no comment, and we can sincerely congratulate the promoters upon it, and trust that their example will be followed in other quarters.

In class I. the models of engines were of the most commendable character. The following is the list :—

1. Locomotive engine. H. Biterlich, brake attendant G.E.R., 2, Ebenezer Terrace, Enfield, Middlesex. £40. 2. Engine and boiler. J. G. Coombs, hammerman, 1, Lismore Circus, Gospel Oak. £25. 3. ½ horse-power horizontal engine. W. Bashford, engineer turner, 53, Paulton's Square, Chelsea. £10. (Commended). 4. Horizontal engine. G. Maze, fitter, 4, Bradley Street, Wandsworth Road. 5. Working model of locomotive. H. C. Ahrbecker & Sons, engineers, 117, Stamford Street, Lambeth. £250. 6. Horizontal engines. B. Garnham, engineer, 39, Redan Street, West Kensington Park, Hammersmith. £20. (Commended.) 7. Horizontal engine. C. Smith, fitter, 38, Fountain Street, Wandsworth Road, S.W. £10. (Bronze Medal.) 8. Locomotive. P. Kraulch, engineer, 117, Stamford Street, S.E. £80. (Commended.) 9. Horizontal slide-valve engine. H. W. Hasteet, iron turner, 43, Camellia Street, Wandsworth Road. 10. Model 7-feet express locomotive G.W.R. I. Ives, goldsmith, 23, F. Street, Queen's Park Estate, Harrow Road, W. £50. (Commended.) 11 Locomotive. R. Arkwright, engine-fitter, L. B. & S. C. R. 16, Raywood Street, Battersea Park Road, S.W. £200. (Silver Medal, Extra Prize.) 12. High pressure steam-engine. J. A. Brooks, fitter, 100, Colegrave Road, Stratford New Town, E. 13. Horizontal steam-engine and boiler. R. R. French, engineer, 81, Rockingham Street, Newington, S.E. £15. 14. Working model steam-engine. R. G. Walduck, hydraulic engine driver, S.W.R., 5, Richmond Place, New Road, Wandsworth Road, S.W. £4. 15. Working model steam-engine. Ditto. £2. 16. Traction engine, A. E. Death, steam sawyer, 53, Sabine Road, Shaftesbury Park. £20. (Commended). 17. Double cylinder trunk engine. S. Garrow, engineer. Pumping Station, Merton Road, Wandsworth. (Silver Medal.) 18. 1 cylinder vertical engine. S. Garrow. Ditto. 19. Engine and boiler. W. Knowles, engine-driver, 34, Sussex Street, Battersea. (Bronze Medal.) 20. Horizontal engine and boiler. W. Attree, joint-maker, 18, Bradley Street, Wandsworth Road, S.W. (Bronze Medal.)

A valuable invention is presented in the "St. Aubin" railway-carriage door lock, manufactured by Mr. Charles Bunn of Herbert-street, West Bromwich. The manufacturer claims for it a superiority over all others, on the grounds that the door upon which it is used can never be closed unless it is securely fastened, and that no turning of the handle is required to close and fasten the door, an operation which can be performed with very moderate pressure, instead of as at present requiring for the purpose a violent slam, irritating to nervous people, and frequently insecure. A projecting peg in the face plate of the lock slides up an inclined slot in the striking plate when the door is pulled to, and this peg withdraws a catch from the end of the bolt, releasing the latter. The turning of the handle to open the door drops the catch again into the bolt, which is thus retained until the door is again closed. The arrangement is an excellent one, providing perfect security. The spring also being triplex, and without any angularities, is not liable to break, an advantage of the greatest importance, and we expect to see it very generally adopted. It will save time to officials, and impart a sense of security to passengers, while its strength, and the readiness with which it may be fitted, is calculated to recommend it to the railway authorities.

CORRESPONDENCE.

RAILWAY SIGNALLING.

To the Editor of "The Railway Engineer."

Sir,—Some time ago the Clearing House representatives agreed to adopt a distinctive shape for distant signal arms to enable drivers to distinguish them from home signals. This has been found of great service where signals are crowded and several arms are placed upon one post, but a distinction is also required for the night.

Some of your readers may, perhaps, be disposed to adopt a system I have to recommend, namely, to place the lights of distant arms on the left, and those of home signals on the right of the post, as shown on Plate CLXXII.

Will you do me the favour of inserting this letter and sketch in your next issue? Yours truly,

H. Johnson, *Superintendent.*

Lancashire and Yorkshire Railway Engineer's Office,
Manchester, *5th October*, 1882.

OFFICIAL REPORTS OF RECENT ACCIDENTS.

Major-General Hutchinson has reported the result of his inquiry into the causes of the collision which occurred on the 14th August last, near Lynn station, on the Hunstanton branch of the Great Eastern Railway. The collision was primarily caused by the negligence of the signalman in the Lynn junction cabin, who, forgetting that he had at 2.33 p.m. allowed the shunting engine and truck to pass on the down Hunstanton line, there to remain about 160 yards from the cabin till the arrival of the up mixed train from Hunstanton, due at 2.55 p.m. (from which train the shunting engine would have had to take some wagons), at 2.43 p.m. lowered the junction down home-signal for Hunstanton to permit the Lynn and Fakenham's special empty train to proceed from the station to Gaywood junction, where the Lynn and Fakenham line leaves the Hunstanton line. He remembered his mistake as the train was passing the cabin, and then tried, but ineffectually, to attract the attention of the driver, fireman, or guard. The driver of the train states that he only became aware of the obstruction when about forty yards from it, the speed being about twelve to fifteen miles an hour, that he had just time to shut off steam and reverse his engine, but that the reversing lever flew back and struck him. The fireman, who was coaling, was able to get a turn at his brake before the collision. The guard saw the obstruction just before the collision, and had time to get his brake partly on. The collision would probably have been prevented had the shunting engine not been improperly left unattended by either driver or fireman. The driver had left it before it started from the yard to get some oil from the storekeeper at the engine shed, and was going to join the engine just before the collision occurred. The fireman, who had taken the engine down to where it was standing, had left it to go into an adjoining field to ease himself, and could not get back to it in time to move the engine ahead when he saw the train approaching. Both driver and fireman are much to be blamed. There was not the least necessity for the shunting engine to leave the yard until the up train from Hunstanton had arrived at the station, and the practice is not to be permitted in future. The junction signalman in this case was performing a spell of fourteen hours' duty, a weekly occurrence, in order to change the day and night shifts. This is certainly a most objectionable arrangement, and one that should on no account be allowed.

Colonel Rich has reported the result of his inquiry into the circumstances, which attended the collision of a goods train with the brick abutment of a bridge over the railway, that occurred on the 15th July last, at the West London junction of the Great Western Railway. The accident was caused by the neglect of the engine-driver of the goods train, who appears to have started his train on receiving notice from the foreman shunter, that the train was ready, and without his obtaining the signalman's permission to go. At the time that the goods engine-driver started, with the intention of running out on to the main line, the points were open for the safety siding, and the disc-signal attached to those points showed that they were so, and that he could not run on to the up line. The main up line signals were lowered for the passenger train from Southall, and it is fortunate that the goods train went into the safety siding, instead of running into the passenger train, which was passing at the moment. I understand that the engine-driver of the goods train stated that he thought that the advance-signal, which was lowered for the passenger train, was intended for him; but this man's statement, that the points were right for him to run out on to the main line at the time he pushed back his train so as to be coupled on to the two wagons and the brake-van, is evidently incorrect. There can be no doubt that he could not have been thinking about his business or he would not have run his train forward while the disc-signal, which was about 170 yards nearer to him than the advance-signal, was against him.

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The Board of Trade returns of accidents and casualties reported by the several railway companies during the first quarter of this year show that there were reported 365 failures of tires, 108 of axles, and 148 of rails. Of the 365 tires which failed, 14 were engine tires, 7 were truck tires, 3 were carriage tires, 10 were van tires, and 331 were wagon tires; of the wagons, 283 belonged to owners other than the railway companies; 312 tires were made of iron and 53 of steel; 18 tires broke at rivet holes, 50 in the solid, 3 at the weld, and 294 split longitudinally or bulged. Of the 108 axles which failed, 65 were engine axles, viz., 61 crank or driving and 4 leading or trailing; 8 were tender axles, 31 were wagon axles, and 4 were axles of salt vans; 11 wagons, including the salt vans, belonged to owners

other than the railway companies. Of the 61 crank or driving axles, 34 were made of iron and 27 of steel. The average mileage of 30 iron axles was 199,578 miles, and of 26 steel axles 190,581 miles. Of the 148 rails which broke, 90 were double-headed, 51 were single-headed, and 7 were of the bridge pattern. Of the double-headed rails, 70 had been turned; 58 rails were made of iron and 90 of steel.

Locomotives on the Great Indian Peninsula Railway.—The cost of the locomotive powers on the Great Indian Peninsula Railway in the half-year ending December 31, 1881, was £269,548, as compared with £213,633, in the corresponding period of 1880. The aggregate distance run by trains in the half-year ending December 31, 1881, was 3,633,125¾ miles to which we must add 310,930¼ miles for miscellaneous engine mileage, so that the aggregate engine mileage for the year was 3,944,056 miles. The company's locomotive stock stood as follows at the close of 1881: Tank engines 59; passenger engines, 102; goods engines, 277; total, 438. Of these the following were in running order at the close of last year: Tank engines, 45; passenger engines, 83; goods engines, 112; total, 340. The cost of the materials used in the repair and renewal of locomotives in the half-year ending December 31, 1881, was £26,846, as compared with £26,706, in the corresponding period of 1880.

Phosphor-Bronze Slide Valves—Exhibited at the North-East Coast Exhibition, Tynemouth.—A pair of slide valves, just taken out of No. 845 express engine of the North-Eastern Railway Company, after 6½ years' working, during which the engine has run 261,182 miles from Newcastle to Edinburgh, and *vice-versa*. They have now been taken out to replace the cylinders with a pair of a different type. Mr. Fletcher, Assistant Locomotive Superintendent, writes as follows upon these slides and another pair still at work in No. 844 express engine:—"Enclosed I hand you mileage of engines 844 and 845, with phosphor-bronze slides, those of 845 being now worn down to the thickness we generally take out gun metal slides. Had it not been that we were putting in a pair of cylinders of a different type, I should certainly have let them run longer, as I consider them quite safe, taking into consideration the great superiority of phosphor-bronze over gun metal. No. 844 engine slides will run for a long time yet. Mileage of 845 engine with phosphor-bronze slides, from March 30th, 1876, to present time, 261,182 miles. Mileage of 844 engine with phosphor-bronze slides, from April 20th, 1876, to present time, 236,229 miles.—Yours truly, Horatio Fletcher, Assistant Superintendent, North-Eastern Railway Works, Gateshead, October 4th, 1882." The original thickness of these slides was 1 in., and they are worn down to ⅝ in. thick. Gun metal slides rarely exceed eight months' work when they are worn out. The cylinder faces are in beautiful condition, the wearing being, as it should be, on the valves. The engines Nos. 844 and 845 are of the following dimensions:—Cylinders 17 in. diameter by 24 in. stroke. Four coupled wheels, 7 ft. diameter, working pressure 140 lbs. per sq. in. Weight of engine in working trim 39 tons 16 cwt. Weight of tender 26 tons 4 cwt. At a fair estimate, from the present condition of the slides, they are capable of from 3 to 3½ years' further work.

St. Louis and San Francisco.—The Boston mountain tunnel, now completed on the Arkansas branch, is 1,693 feet in length. It is 190 feet from the grade of the tunnel to the summit of the ridge. The principal material found in the tunnel was a hard black shale, indicating that coal may be found in that formation. The tunnel is lined throughout with heavy oak timbers, and 30 feet at each end is protected by a brick arch and stone portal. The cost of the tunnel and approaches has been about 200,000 dols. The work on the tunnel proper was commenced September 26th, 1881, and the track was laid through on July 27th, 1882, consuming about ten months in its completion. The track in the tunnel is 1,727 feet above the sea level, or 1,300 feet above the city of St. Louis. The average height of the Boston mountains is about 2,300 feet. The completion of the railway to Fort Smith will make it quite a summer resort for the people of the Arkansas valley. The track beyond the mountains will probably be open to Mountainburgh, 16 miles north of Van Buren, early in September, and will be open to Fort Smith some time in October.—*Missouri Republican.*

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RAILWAY SIGNALLING.

(*Continued from page* 298.)

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THE chief, or most important requirements of the Railway Inspecting Officers of the Board of Trade, relating to the arrangement, working, and interlocking of signalling appliances, are principally incorporated in the 4th and 6th clauses of their memorandum, which are as follows:—

"4.—The levers of points and signals should, as a rule, be brought together under cover upon a properly constructed stage, with glass sides enclosing the apparatus. They should be so arranged that while the signals are at danger the points shall be free to move; that a signalman shall be unable to lower a signal for the approach of a train until after he has set the points in the proper direction for it to pass; that it shall not be possible for him to exhibit at the same moment any two signals that can lead to a collision between two trains; and that after having lowered his signals to allow a train to pass he shall not be able to move his points so as to cause an accident or to admit of a collision between any two trains. The facing points should be provided with apparatus which will ensure the points being in their proper positions before the signals are lowered, and which will prevent the signalman from shifting the points whilst a train is passing them. Every signalman should be able to see the arms and the lamps of the home as well as the distant signals, and the working of the points or of the indicators showing their position, the back lights of the lamps being made as small as possible, having regard to efficiency. When the front lights are visible to the signalman in his cabin, no back lights should be provided. The fixed lights in the signal-cabins should be screened off, so as not to be mistakeable during fogs for the signals exhibited to control the running of trains. If from any unavoidable cause. the arm or lamp of any signal cannot be seen by the signalman, a repeater should be provided in the cabin. Clocks should be placed in conspicuous positions for the use of the signalmen."

"6.—It being necessary that a uniform system of signals should be adopted on all railways, the semaphore arms should, at junctions, be on separate posts or on brackets; and at stations, when there is more than one arm on one side of a post, they should be made to apply,—the first or upper arm to the line on the left, the second arm to the line next in order from the left and so on; but in cases where the main or more important line is not the one on the left, separate signal posts should be provided, or the arms should be on brackets.

"Any signal which is worked by a wire or rod should be so weighted as to fly to or to remain at "danger" on the fracture of the wire or rod.

"The distant-signals should be distinguished by notches cut out of the ends of the semaphore arms where such are employed. In no case should a distant-signal arm be placed above a home-signal arm on the same post for trains going in the same direction. In the case of sidings, a low and short arm, distinct from the arm or arms for the passenger lines may be employed.

"The junctions between passenger lines and goods and mineral lines and sidings should be protected by home and distant signals. The sidings should be so arranged, that the shunting carried on at them shall present the least possible obstruction to the passenger lines."

From the above it will be seen that the Government requirements are not remarkably exacting, nor possessing features of any cogent originality, but rather suggest the more universal adoption of ingenious appliances and precautions long previously devised and advocated by our railway engineers. But although railway companies are usually desirous of possessing efficient safety appliances, not only for the welfare of the public as also that of their shareholders' pockets, yet they are frequently too tardy in giving fair attention to developments of inventive genius, unless they originate, or be directly fostered by some of their own staff.

Of course there must obviously be a practical limit to the countenance of all praiseworthy inventions, as the professed supply is far in excess of the demand.

The question of great "simplicity" throughout all departments of Railway working, is a point on which much confusion, misunderstanding, and disagreement has commonly arisen.

On several occasions, no particularly mild invectives have been hurled against the Board of Trade, as inventing or requiring complications, objectionable to the views of some railway engineers or authorities. But perhaps it is the happy medium which is the best, and most amicable view to take of the question. For although "simplicity" *per se*, is of prime importance, yet some further qualification of the term is required to reconcile facts. Simplicity in constructions does not necessarily mean simplicity of operation, as it is not an uncommon practice in machine design and construction to apparently complicate the elements in either number or functions, that a simple and reliable result may be obtained. For example, some years ago, signal-posts, with one arm for two conflicting roads, were occasionally placed at junctions,—a provision remarkably simple, but an arrangement unfortunately possessing the peculiar disadvantage, that when two trains happened to simultaneously approach the junction, neither of the drivers could feel certain for whom the signal was intended, so that in some cases they settled any differences of opinion by continuing their course, and ultimately colliding with each other. After several accidents resulting from such mistaken notions of simplicity and economy, the Board of Trade prohibited their use.

As far as crude simplicity may be interpreted, nothing could much surpass the employment of hand signals, which have been long since, as much as possible, discarded as inefficient and unreliable. Some few years ago Sir Edward Watkin, whilst addressing the Shareholders of the Manchester, Sheffield, and Lincolnshire Railway, most openly expressed his aversion to the requirements of the Board of Trade, stating :—

"My notion of working is simplicity. These things increase complication. The Board of Trade requirements tend to make the thing complex, to make it difficult, and to multiply the causes which lead to error ; and I think myself, if you will take the average of ten years after we have got all these new-fangled things into operation, it will be shown that the old simple arrangements of Stephenson, Brunel, and Locke, are best ; and, after all our experience, we may have to come back to the simple way of working, and to put many of these new-fangled things into the fire."

Mr. Forbes, Chairman of the Metropolitan Railway Company, very shortly afterwards followed suit, and made the following statement at one of their half-yearly meetings :—

"The item of compensation had been £5,000 extra in the half-year, with which they had really nothing to do. The accident was caused by one Metropolitan train running into another Metropolitan train, and they had to pay one-third of the cost under the agreement with that company. He complained that under the direction of the Board of Trade, they were obliged to use apparatus that had caused accidents, and had entailed a loss of £18,000 in damages, which he thought very hard indeed."

Again, Sir Daniel Gooch, at a meeting of the Great Western Railway Shareholders, expressed his views, which were of the same nature as the above. He said :—

"We complain of the mechanical arrangements and contrivances, and different things that are forced on railways contrary to the opinion of the railway engineers and officers who are responsible for working the railways, and who have had experience to enable them to judge of the efficiency or otherwise of these contrivances. Therefore, we say—and we say it very strongly—that the contrivances of the Board of Trade, to the extent to which they are forced upon us, are increasing the danger of our railways."

Since the date of such statements, years of practical tests with various railway appliances have elapsed, and we now find past sceptics amongst the foremost believers in mechanical devices rather than of man.

The incontrovertible advantages of the "Block and Interlocking systems" are now scarcely likely to be questioned by any intelligent person, considering their daily operation in the busiest railway centres of the world.

The only point of objection that could then be raised against such invaluable systems, were quibbles on grounds of expense. But although the various appliances and amount of attendance looked individually serious items, yet when we come to realize that to provide an average railway with complete Block and Interlocking apparatus, only means about ·5 per cent. of the total expenditure upon the construction, we think there can remain at the present time very little difference of opinion as to the value of such small investment upon the total prime cost. The maintenance of the systems is also not so seriously large as once represented. The maintenance of the Block System, which is the greater expense, only means an average expenditure of about 2 per cent. upon the total receipts or revenue of a railway, which is comparatively insignificant when we consider the probable amount that would otherwise have to be expended as compensation for injuries to passengers and goods, through accidents resulting from inefficient signalling arrangements.

That the question of compensation from such causes is no bagatelle, may be roughly appreciated by the following statistics, taken from the returns of a recent year (having a low average of accidents), notwithstanding the provision of comparatively modern appliances for minimising such frightful and expensive calamities.

The London and North Western Railway Company paid in compensation for personal injuries £28,386, and £41,086 for damages to goods, in the course of the twelve months. Similarly, the Great Western Railway Company £20,000 for passengers, and £27,830 for goods; Great Northern Railway Company £13,000 for passengers, and £11,800 for goods; South Western Railway Company £21,500 to passengers, and £9,500 for goods; South Eastern Railway Company £12,600 to passengers, and £5,960 for goods,

respectively, besides numerous other companies' liabilities, all within the same period. From the above it will be readily gathered that although, fortunately, railway accidents of any importance are now comparatively rare (considering the colossal nature of our systems, and the number of passengers and amount of goods carried), yet whenever they do occur, no matter how small, the liabilities of the railway companies are considerable. We may form some idea of the safety of railway transit and the precautions observed in working the same, when we appreciate that on an average there is only one person killed, and one injured, in about every 4,380,000, and 430,000 passengers carried respectively.

Punctuality in the arrival and departure of trains is a matter of great importance in maintaining safety of traffic, as it much reduces the risks attaching to human fallibility; for when the order of traffic is altered or rendered irregular by unpunctuality, the attention of the railway servants is much taxed. Taking the "time returns" of an average punctual year, for example 1880, we find that out of 110,700 passenger trains starting in one week, 56,304 kept absolute time; 26,650 arrived within five minutes of their time; 19,532 not more than fifteen minutes late; and 8,214 trains over fifteen minutes after their booked times. And this is taking no account of the extreme irregularities of goods traffic.

We now pass on to briefly discuss a few important points in regard to signalmen. For however complete and automatic the mechanical and electrical apparatus may be, still we are, and must be, more or less dependent upon some human superintendence or control. And although much has been meritoriously devised to reduce the liability of errors by such class of men, yet we should recognize and appreciate a very valuable community in this department of the railway world.

It is not uncommon to hear opinions expressed to the effect that it would be desirable that a more intelligent class of men should be engaged for the services of signalmen, as the duties still daily requiring their vigilance and attention are of no slight importance. But, on the other hand, it must be remembered, that at present the remuneration of signalmen is by no means conducive to reserve the services of promising men, who naturally aspire to some occupation in the railway world of a more lucrative character.

While others again argue that no such high degree of proficiency or ability is necessary for the duties of modern signalmen, as so much responsibility has been removed by the introduction of efficient mechanical safety appliances. But, nevertheless, it cannot be lost sight of by those competent to judge in the matter, that duties of no insignificance are daily in the hands of this useful body of men; for, notwithstanding the mechanical precautions and preventives to dangerous blunders, yet there unavoidably remain many easy loopholes for repeated errors of manipulation, which might result in the most disastrous consequences. The lack of immunity from danger from such causes will be readily perceived, when we consider the serious opportunities for conflicting operations between the block or electrical, and the mechanical or interlocking systems, which liabilities we hope to soon see materially reduced, if not practically removed by the introduction of the "Union of the lock and block systems."

As an example of such present liabilities, we need refer to no remote period, as the "Cannonbury Accident" has scarcely passed from our minds.

The usual wages of signalmen is at present from twenty to thirty shillings per week, and is, we think as most of our readers will agree, no prodigal expenditure on the part of the railway companies for the services they receive. Some railway companies give a small bonus every three, six, or twelve months to certain signalmen who have exceptionally distinguished themselves during their arduous labours. Signalmen, like most other divisional representatives of technical labour, are not entrusted with positions of responsibility until they have served some years in the various grades of such occupation. A competent signalman is not only required to be thoroughly conversant in the working of the appliances in his own box, but also those of both boxes on either side of him, with which he is in daily communication. From practical experience of many railway companies, sailors have proved to make excellent signalmen, whilst soldiers, on the contrary, appear to possess little, if any, capabilities for such occupation. The usual period of daily employment of signalmen, is from eight to ten hours daily, according to the locality or nature of traffic to be controlled; whilst a large additional staff is always retained in reserve for relieving men during meals, on Sundays, or in cases of sickness. Usually, before a signalman is certified as proficient, he has to prove his knowledge of the mechanical and electrical instruments to be placed under his control, as also reading and writing, the companies rules, &c., and unimpaired sight for judging colours and distances.

We now bring to conclusion our series of papers and remarks upon the "Out-Door or Mechanical Systems of Railway Signalling and Safety Appliances from their Infancy to the Present Day;" and in some future publication we shall direct our readers' attention to the indoor or electrical sequel to the subject. The essentially mechanical portion of the subject has probably been more exhaustively treated than hitherto attempted in any language; in fact, it appears to be a division of technical literature previously much neglected, considering its vast importance, and direct or collateral interest to the intelligent portion of the civilized world, which have experienced the inestimable value of railway communication. In performing such pleasant task, we cannot nevertheless but feel convinced that our labours have been necessarily imperfect, and have encroached upon grounds on which most varied opinions exist.

The English people are essentially a travelling nation, confining their professional and commercial industries to no particular cities or lands, and therefore a community much interested and dependent upon the modern facilities of speedy and safe locomotion by land or water. And so far as railway systems are concerned, we are proud to observe that our English engineers have from the com mencement unquestionably led the way, and still continue, by their intelligent and well-directed energies, to maintain their deserved superiority.

From the first inauguration of the iron-road, the important question of means for effecting the safe conduct of traffic thereon, was by no means overlooked or underrated. In fact, without the attainment of some degree of efficiency in this direction, railway transit would have been hopelessly retarded, and rendered comparatively valueless. The important and indispensable part that electric agency has played in arriving at such necessary degrees of efficiency, will be justly assayed in some future papers. To thoroughly appreciate the development and advantages of modern locomotion, we should take a brief retrospective glance at the means at the disposal of our fathers; and, doubtless, it will be even within the memory of some of our readers, when the "Edinburgh coach" used to be advertised to leave that city, "with God's permission," once a month for London, a journey then occupying from ten to twelve days, but now daily performed in a less number of hours.

According to present arrangements for travelling, one is now enabled to go to St. Petersburgh and back in less time than that originally occupied between Edinburgh and London. In such days of early locomotion, the means of travelling were not only lamentably tedious, but only open to comparatively few, both on the score of accommodation and expense; whereas, at the present time, the poorest are capable of reaping the benefit of railway intercommunication. Some notion may be gathered as to the colossal service of our modern railway systems, when we consider that about 600,000,000 persons are annually carried upon the railways of our United Kingdom, which large number is not so remarkably surprising when we appreciate that over 60,000,000 of passengers are conveyed by the Metropolitan Underground Railway alone in the course of twelve months.

At the first glance, such figures are almost beyond comprehension; but when we consider that the *Times* newspaper is estimated to contain about an average of one million of letters in each issue, we may form some rough idea what sixty or six hundred times such number of persons must mean.

From a commercial point of view, our present railway systems are no less important, when we recollect that upwards of £700,000,000, (a sum almost equal to the National Debt,) has been expended on them, and most of them class well as stable investments amongst our home securities.

How truly surprised would some of Stephenson's antagonistic contemporaries be if they could only now see the progress made in railway enterprise, which in their days was looked upon as a hair-brained inventor's scheme! The press opinions of those days which denounced as absurd the idea of being able to travel twice as fast as stage coaches by the aid of steam power, comparing it with the probability of the populace of Woolwich suffering themselves to be fired off in one of Congreve's war rockets, now read truly ridiculous in the times of our present express trains. Such then are the achievements of modern engineering skill and perseverance. How true were the words of John Bright, one of England's greatest orators, when he pithily stated in the House of Commons that our engineers had done more for their country than warriors or statesmen.

So far as signalling is concerned as an important branch of modern railway engineering, we find it assimilates itself alike to the locomotive superintendent and civil engineer, as also to the traffic and general manager of the line.

Glancing at the progress made by our continental brothers in this and kindred branches of railway work, we can without any egotism state, that they are still comparatively much in our rear. The "Block and Interlocking systems" are essentially English inventions, and were comparatively slowly adopted upon continental lines; whilst facing point locks and uniformity of signals appear still much neglected. Disc and semaphore signals with unsightly and unmeaning protuberances seem used indiscriminately, whilst with a few exceptions, concentration of working appears almost entirely ignored.

On the Continent, audible signals, such as gongs, whistles, and horns are employed to a considerable extent, the inharmonious cadence of which strikes the ear of the English traveller as extremely strange. Likewise a large amount of similar intelligence is communicated by the use of flags or poles, analogous to the signalling operations at military manœuvres. Distant and other signals are commonly dependent upon some local and unreliable source of operation, such as through the agency of some unsophisticated rustic or plebian, who is allowed to economise time by combining his signalling services with agricultural pursuits. It is by no means uncommon upon the continental country lines, to see a rustic suddenly summoned from his labour of the soil, by the discordant strains of some unearthly wind instrument, to raise or lower a signal through the tedious intervention of a small winch, which winds a chain upon a drum,—an expedient by no means remarkable for its rapidity of operation, or mechanical skill expended upon it. The valuable and rapid movements obtained by the use of levers, appears by them for some unaccountable reason much discarded, and even in such cases where these devices are employed, the spring-catch-rod contrivance seems almost

unique. Stranded galvanized wire for signal-pulls, also appears to be a manufacture unknown in these parts, whilst the use of guide pullies in connection with it are likewise apparently considered surperfluous luxuries, as stakes of wood with burnt holes are found to be simpler expedients. Of course, it hardly remains to state, that if continental railway traffic was conducted at the speed, and upon the colossal scale common to this country, some more efficient arrangements would have to be employed. Now some of the large continental termini in busy districts, have been equipped with more modern appliances, which in most cases are done by English engineers. The fastest express trains in France now travel at an average of 63 kilometres (not allowing for slowings or stops), which is ten per cent. behind the speeds of such trains as our Flying Scotchman, Irishman, and Dutchman, &c., which average under the same conditions about 73 kilometers. Passenger trains in France are not allowed to pass through junctions at a speed exceeding 20 kilometres per hour, so that in this manner much time is lost which is not considered in the above comparison. Whereas, some of our Scotch expresses attain an average velocity of fully 77 kilometres per hour, after having to pass through about 145 junctions in a distance of about 300 kilometres, as for example between London and York.

Reverting to the colossal character of most of our railway systems, it may be interesting as well as amusing to some of our readers to cite a few popularly compared facts with reference to the capacities of the North-Eastern Railway Company, as pointedly narrated by Mr. Tennant, General Manager of the line, at a banquet given to their employés. This gentlemen went on to demonstrate in a popular manner, within the grasp of the most commonplace intelligence, the great undertakings and achievements of modern railway enterprise, and for this purpose he naturally could not do better than enter into comparisons based on their own line, with which they were obviously best acquainted.

As regards their rolling-stock, he informed them that their engines if put together—end to end—would extend to a distance of over 11 miles, whilst their carriages and wagons if similarly combined, would reach a distance of over 270 miles, or about to a distance from Newcastle to London.

As to the performances of their engines, he went on to state, that in that year they had travelled an aggregrate mileage equal to about 900 times round the world, or more than $2\frac{1}{2}$ times the circumferential distance of the world every day. The minerals conveyed by the company's trains in the course of twelve months had been sufficient to form a tower 400 yards square and $1\frac{1}{2}$ miles high.

Referring to their Revenue department, he assured them that the amounts of money received would, if taken in five pound notes, be sufficient to cover an area equal to eight acres, whilst if considered in sovereigns placed in successive contiguity, would extend to a linear distance of 87 miles in length.

Subsequently, Mr. Tennant proceeded with some amusing comparisons as to the accommodations for railway transit and the numbers of passengers annually conveyed between various localities by the various companies within the Kingdom. Taking the latter at about 600,000,000, he went on to inform them that a period of 1,500 years would have to be occupied if one smart booking-clerk had the pleasing task of issuing all the tickets for such number of passengers, and even then he would have to work at the rate of issuing two tickets a minute for ten hours every day within the stated period.

Such then are some of the many truly marvellous attainments of the developments of engineering science, the future course and termination of which it is impossible for any of us to pretend to foretell, but rather should we be disposed to concur with Daniel Webster's conclusion, that :—" What further improvements may still be made in the uses of this astonishing power is impossible to know, and it were vain to conject. It seems to say to men—leave off your manual labour, give over your bodily toil, bestow but your skill and reason to the directing of my powers and I will bear the toil, with no muscle to grow weary, and no nerve to relax."

SHAFFER'S PATENT SIGNAL LOCK.

We this month give on Plate CLXXIV. the first half of a series of drawings illustrating Shaffer's Safety Lock and Signal System, as promoted by the Railroad Safety-Lock and Signal Company of Camden, N.J., U.S.

We print the whole of the description now, though the remaining drawings will not appear till our next issue. The lettering is the same for all Figures.

Figs. 1 to 1*b* are isometric views of the lock and signal.

Fig. 2 is a Plan of the system as laid out on a single line of rails, and Fig. 2*a* the same on a double line.

Figs. 3, 3*a*, are views of the rail connection or valve tripping bar *H*. It is secured to inside of hind driving axle-box of engine. The slot *m* in rod *l*, connecting it to the bell-crank *c*, permits the backing of engine without actuating the stopping mechanism.

Figs. 4, 4*a*, are Elevation and Plan of the track incline, to be struck by the rail connection or valve tripping bar *H* on the engine. When the track is clear, to be depressed one inch. The sides are sharpened to scrape off ice. Figs. 5 to 7 are details. This is also seen in isometric perspective at I, Fig. 1.

Figs. 8 to 9*a* are the cylinder *B* with details, for closing throttle and blowing whistle.

Figs. 10 to 10*e* represent the self-closing valve, shewn also in isometric perspective at Fig. 1*a*. When the lower end of bell crank *c* is pulled, the roller *h* rests on the top incline of spring *e* at *é*, the spring *e* then forces head of valve *p* (Fig. 10*b*) on its seat *r*, and the head *q* is moved from its seat *s* against the steam pressure, when steam or water passes through pipe *i* to cylinder *B* (Figs. 8 and 13.) The upward movement of arm *d* of the bell-crank *c*, also permits air to escape, or to enter brake pipe *k*. The engineer when wanting to start, places his foot on *x*, the the top of rod *g* running through floor of cab, and forces roller *h* down to catch, or depression of spring *e*, when the valves closes automatically.

Figs. 11 to 12*a* represent the auxiliary rail and device to prevent tampering. The locking device and circuit-closer cannot be moved unless the weight of an engine or car is partly distributed on the lock-rail *Q* at the time of such movement. When the weight of a locomotive or car-truck is on the lock-rail *Q*, this rail is depressed. Locks *N* and *M* are raised from catches in rods *O* and *P*, which can then be revolved. After such revolution they fly back to their normal position where they are so held until the approach of the next train.

Figs. 13, 13*a* show the general method of application to a "Baldwin" Passenger Engine.

Fig. 14 is a free-hand drawing, showing the actuation of gravity and electricity.

Figs. 15 to 15*c* are an enlargement on Fig. 14, consisting of electrical details. Whenever the circuit is broken, the danger signal resumes its normal position, *danger*, and the track incline cannot be depressed.

The operation is as follows:—An engine *A*, in passing point 1 (Fig. 2), with tripping car *H*, depresses track incline *I* (Figs. 1, 4 and 4*a*) one inch, which causes track arm *J* to move downward and revolve rod *P*, which in turn pulls down yard rod *G H* and bar *B* (Figs 14 to 15*c*), when roller *R* (same Figs.) pulls circuit-closer *E* to insulated rest *U*, (position 1, Fig. 15*c*), thus breaking local electric circuit at at Point 1, (Fig. 2) and simultaneously at Point 3 on the *other side* of the track. When the bar *H* has passed the incline *I*, the latter again moves to its normal or higher position by means of a spring *X* encircling the rod *H*, (Fig. 15), and carrying bar *B* with it to its highest position. The circuit having been broken (through shifting of *E*), weight *W* causes lock *A* to drop under bar *B*, and thus hold it, and track incline *I*, rigidly in its higher position. As bar *H* of engine *A* passes point 2 it performs the same functions, and so on indefinitely.

Now if a following train should approach Point 1, the track incline *I* being immovable, and being one inch higher than the lower tip of bar *H*, it, bar *H*, would have to move backward against and bow its spring *F*, until its lower end had risen enough to clear incline *I*. Pin *n* of car *H* would then pull rod *l*, and bell crank *c*, until roller *h* had mounted incline *é* of spring *e*. The spring *e* being thus released would press against valve stem *o*, until it had forced valve head *p* (Fig. 10*b*) to its seat *r*, and opened valve head *q* from its seat *s*. The water or steam would then rush in valve *a*, through pipe *i*, to cylinder *B*, (Figs. 8 and 13) when cords *C* and *D* would be pulled down by piston of cylinder *B*, thus shutting off steam, and blowing whistle. When connecting bar *d* is raised with bell-crank *c*, it permits spring *f* to pull stop out of pipe *k*, and thus opens brake-pipes, and brakes the train simultaneously with the closing of throttle and blowing of whistle.

Should engine *A*, however, have passed Point 3 (Fig. 2), the circuit-closer on rear truck of train (Fig. 1*b*) would have depressed arm *K* (Figs. 1 and 11 to 11*d*), and caused rod *O* to revolve and pull down rod *T* (Figs. 15 to 15*b*), compelling platinum plunger *u* to enter mercury *v*, and thus close circuit at Point 1, when the *other* magnet at Point 3 also closes in unison—the armature pulling lock *A* from under bar *B*. The lock *A* has attached to it an arm *D*, which presses against screw *d* (Fig. 14), and forces circuit-closer *E*, to conducting rest *V* (position 2 Fig. 15*c*), where it remains until another train passes, and the signals at Points 1 and 3 are clear.

Now should the engineer wish to proceed, he places his foot upon *x* (Figs. 1 and 3), pushes down rod *g* with bell crank *c*, until roller *h* again rests in depression of spring *e*, when valve stem *o* (Fig. 10*b*) being released from pressure of spring *e*, the steam pressure instantly forces head *q* into its seat, and thus automatically closes valve; and head *p* leaving its seat *r*, permits water to discharge itself at *y*. The connecting bar *d* meanwhile has placed the stop of spring *f* in position to close brake pipe *k*. The engine is now ready to proceed.

Whenever a switch is misplaced, or a drawbridge is opened, the circuit is broken and everything locked, and danger signals shown for two blocks in either direction. At points where avalanches or landslides may occur, or where there is danger of tunnels caving in, guards are placed, which the moment they are broken or moved, break the circuit, and thus stop the train, the same as misplaced switches.

Should an engineer or driver find signals against him, and see the train he is following leaving the station beyond where he is signalled, and where he would be obliged to stop, he may proceed without stopping by simply placing his foot on rod *x* in floor of cab. As the pipes

leading to stopping mechanism are purposely made small-in order to prevent the severe shock which follows the too rapid checking of a train from a high speed, before the cylinder could act he could close the valve, and then pass along unretarded.

Where all the locomotives on a line are not provided with the Valve Tripping Bar, a lever is placed beyond the locking box under the rails, to be actuated by the weight of engine, thus breaking the circuit, throwing the signals to danger, and locking the incline, the same as though so provided.

The circuit-breaking arm (Fig. 1*b*) for use on rear car is made light, and is easily handled, so that it can be moved from car to car as may be desired, the same as a lamp or a flag.

BRIDGE OVER THE TEES, STOCKTON.

THE bridge which forms the subject of our illustration is being built by the side of an existing one designed by the late Robt. Stephenson, which carries the Stockton and Darlington Branch of the North Eastern Railway across the Tees at Stockton. It is intended for the accommodation of a pair of mineral lines, and when finished it will complete the separation of the mineral from the passenger traffic by means of independent lines for the whole length of the iron-making district of Stockton, Middlesbro', and Eston.

It is of the simple and substantial type adopted on many parts of the North Eastern Railway, and its construction does not present any striking or novel features. A few particulars may, however, be of interest as a record of current bridge practice.

The bed of the river consists of a bluish loam, locally called "Warp," and very soft. Borings were carried down some 50 ft. below the bottom, in hopes of reaching the solid clay to which the piles of the old bridge were driven. Nothing, however, was met with but sand and thin beds of gravel. Ultimately it was decided to found on the sand at a depth of 30 ft. below the river bed. This is quite deep enough to be out of reach of any possible scour or other disturbing influence and it has made a good foundation.

The cast iron cylinders forming the shell of the piers, were carried out according to the drawings, with the exception of the bottom or cutting length, which was made 2 in. instead of 1 3-8 in. thick as shown. The whole of the joints were planed and caulked with rust cement when put together, and all cylinders below low water mark were dipped in boiling tar and pitch.

As the cylinders were sunk, the excavation was carried on from the inside by means of a mechanical grab or excavator, worked by an engine on the gantry overhead. This excavated the loam satisfactorily, but in the clay slow progress was made. The excavation in all the cylinders was finished by hand, the water being excluded by pneumatic apparatus; the actual bottom upon which the piers rested could therefore be inspected, and samples from each pier have been preserved.

As soon as a satisfactory bottom was reached, 16 ft. of concrete 4 to 1 was put in, and as soon as this set the pneumatic apparatus was removed, and the brickwork filling was got in, in the open, no trouble being experienced from leakage in any form.

On the completion of the piers to within one cylinder length of the caps, a test load of 275 tons was applied. This with the weight of the pier itself gives a pressure of 6·36 tons per sq. ft. upon the foundation. Under this load the piers settled variously from $2\frac{7}{16}$ in. in one pier to $\frac{1}{8}$ in. only in another; the average settlement of the eight being $1\frac{3}{8}$ in.

In all cases the load was allowed to remain on until the pier had stood some days without settlement. When completed the pressure on the foundations will be 4·45 tons per sq. ft. when the bridge is unloaded, and 5·75 tons per sq. ft. when it is loaded with $1\frac{1}{4}$ ton per running foot on both lines.

The capitals of the piers are carefully finished off with lead so as to exclude water, and the effect of them is neat and pleasing.

The superstructure consists of 6 main girders weighing about 38 tons each, four shorter main girders of $7\frac{1}{4}$ tons each, 38 cross girders of $3\frac{1}{2}$ tons each, and 172 rail girders varying from 5 to 7 cwts. each, making a total of 485 tons, which at £14 per ton works out to £6796. The total cost of the superstructure, including way beams, planks, and everything ready for permanent way, works out to 14s. $8\frac{1}{2}$d. per sup. ft. The strength is calculated for a rolling load of $1\frac{3}{4}$ tons per foot, and for $16\frac{1}{2}$ tons as the greatest weight on any one pair of wheels.

The wrought iron was specified to be of the best Cleveland make, and all plates were to stand a tensile strain of 20 tons per sq. in., and all angles and tees 22 tons.

Every delivery of plates was tested, and the following is the average of 90 tests:—Fractured with 22·32 tons per sq. in. tensile strain. Extension 13-16 in. per 12 in. or 6·7 per cent. Reduction of area at point of fracture 9·05 per cent.

The total cost of the bridge is £15,405. It has been designed by Mr. Wm. Cudworth, Memb. Inst. C. E., under the superintendence of Mr. T. E. Harrison, Past President Inst. C.E., and Mr. W. J. Cudworth has had charge of the works. The contractor is Mr. Walter Scott, of Newcastle, his resident agents being Messrs. Middleton & Bonthron, and the sub-contractors for the iron-work are Messrs Wilson Bros. & Co., of Darlington. The works will probably be completed about the end of the year.

MORRIS'S AUTOMATIC RAILWAY SIGNAL.

—:o:—

IN connection with the Morris Automatic Railway Signal, illustrated on Plate CLXXV., we have received the following :—

The present system of signalling to engine drivers in foggy weather, or when from any other cause the fixed signals are not visible, by means of fog signals, entails great expense on railway companies, serious inconvenience and anxiety on station masters, and on platelayers very arduous duties no-unattended by danger, and is generally admitted to be un satisfactory.

The suddenness with which a fog sometimes comes on renders it impossible to have the platelayers or fog men in position on every occasion, as was clearly shown by the evidence given at the inquest after the Hornsey accident last January.*

Numerous alternative schemes have been suggested, but hitherto the absolutely reliable working of the signal has not been sufficiently assured in any one of them to lead to its adoption.

This system offers even greater security than is found in the present one ; is very simple in its mechanical details, and the cost would probably be more than met by the saving of platelayers' wages and expense for fog signals in a single winter on any line where there is a fair amount of traffic.

Before describing the figures it may be as well to give an outline of its main features.

IN TRAINS FURNISHED WITH AUTOMATIC PRESSURE OR VACUUM BRAKES the passing of a signal at "danger" causes the gong on the tender to be struck, and, by a very simple arrangement, a gradual application of the brake at the same time, and while the brake is going on an air whistle on the brake pipe is continuously blown. The driver has thus THREE intimations that he has passed a signal at danger, viz., the gong, the air whistle, and the application of the brake, which, although gradual, he instantly feels.

If desired, the application of the brake may be so regulated by the size of the valve as even to bring the train to a stand, or at all events to a very slow speed, in what may be considered an average number of yards between "distance" and "home" signals, should no attention be paid to the signal.

Of course the brake is not wanted at the "distance," and the driver or stoker would immediately close the valve on hearing the gong and whistle; they would, however, know whether the brake was in working order at the "distance,' and in the event of its not being so, an accident might possibly be avoided by shutting off steam in proper time, instead of keeping all on to the last yard, relying on a powerful brake for a smart stop in the station or elsewhere.

FOR PASSENGER AND GOODS' TRAINS NOT FURNISHED WITH AUTOMATIC BRAKES, in addition to the mechanical blow on the gong, a continuous ringing on the gong, or on a small bell, is kept up by the forming of an electric circuit. A small electric bell placed near the steam gauge on the locomotive would probably be the best arrangement, and this bell, right in front of the driver, would continue to ring after the passing of a "danger" signal and the gong had been struck until the small lever or handle, the depression of which had completed the electric circuit, had been again raised to its ordinary position. For this purpose a Leclanche battery is all that is required ; and in a box, say twelve inches square, which might be stowed away in any convenient place on the tender, there would be ample room for two of them (the second as a reserve), although it is scarcely necessary to have more than one, since the battery, once charged, will retain sufficient power to ring the bell for twelve months, or even longer, without being touched.

The cost of this electric arrangement is a mere trifle.

There are two other important features in this system, viz., AN AUTOMATIC TEST OF THE GONG AND BRAKE, OR ELECTRIC APPARATUS, ON THE DEPARTURE OF THE TRAIN FROM THE TERMINUS, and an arrangement by which THE MAN IN THE SIGNAL CABIN INSTANTLY KNOWS AS HE WORKS HIS LEVER WHETHER HIS SIGNAL IS RIGHT OR WRONG.

The first is effected by having a swinging arm placed between the rails on the departure side of the terminus. This arm is not connected with any signal wire, but simply has a light counterpoise sufficient to maintain it constantly in a vertical position, except in the case of shunting, or of a train or an engine backing into the station, in which case it swings into a horizontal position, as the tappet under the tender comes in contact with it. On the departure of the train, however, it retains its vertical position, and causes the gong to be struck and the brake applied, or the electric bell to be rung. It follows, therefore, that the driver or stoker must necessarily have his attention directed to the brake (in trains furnished with automatic brakes) that he may close the valve immediately the brake whistle is blown, otherwise he would have a difficulty in starting. In the case of the electric appliance the bell would ring until the handle was raised; or if it did not ring, the driver would know the battery required attention.

The way of letting the signal man know the exact position

* William Daniels, engine driver, stated, "Although the fog was very bad, there were no fog men out at all;" and Mr. Clayton, the station master, said the fog came on so suddenly that he had not time to send out platelayers with fog signals before the accident occurred.

of his signal is by means of an electric indicator, placed in front of him over this lever in the cabin, which shows a red disc when the signal is at "danger," and a white one when the road is clear. When the swinging arm is at a vertical position, *i.e.*, at "danger," the counterpoise presses on a stud placed in a box in the ground, and this pressure completes an electric circuit with the cabin, and the red disc is seen. The stud is furnished with a spring, which forces it out when the counterpoise is raised ; or, in other words, when the arm is not vertical, thus breaking the contact, when the white disc is seen in the cabin, which signifies the signal is at " clear." It therefore follows that if the white disc be seen instead of the red one, the signalman instantly knows that the arm has not swung to its vertical position ; on the other hand, if the red disc be seen instead of the white one, he knows the signal wire must be broken, for under no other circumstances could the arm be in a vertical position when the lever was pulled for " clear." In the event of the wire breaking, the signal therefore goes automatically to " danger."

To describe the drawings, Fig. 1 represents the side elevation of a tender and rails partly in section, and Fig. 2 the end elevation, in which A is a swinging arm with counterpoise (shown in larger scale in Fig. 5), and upon which the tilting rail or plane BD rests.

The plane BD has a counterpoise at C, the weight of which is so adjusted as to permit of BD falling level with, or below the rails, when the arm A is pulled to a horizontal position (as seen in Fig. 5) by means of the chain which passes over guide pulleys, and which is connected with the signal wire from the cabin—or, in other words, when the signal is pulled for " clear,"—and at the same time to permit of BD being easily raised to its position in Figs. 1 and 2 when the fall of the counterpoise on A causes the arm to assume a vertical position, when the lever is pushed over for " danger," or in the event of the wire breaking.

The swinging arm A and the plane BD are placed between the rails, but out of the centre, in order to avoid contact with any loose couplings ; they may, however, if found more convenient, be placed outside the rails with a corresponding arrangement on the tender.

The curve at the end of BD is so placed that in the event of shunting, when the signal is at " danger," the roller on the tappet under the tender runs up it the reverse way. Under the tender, the shaft E, supported by the bearings FF, has upon it two tappets GG, furnished with friction pulleys (the second tappet being only required in the case of tender running before the engine) which are placed at such an angle that the friction pulley comes in contract with BD when the signal is at " danger," up which it freely runs, and in doing so the crank on the end of the shaft E pulls down the rod H, which in its descent raises, by means of a spring catch, the hammer J (Fig. 3) and so causes the gong K to be struck.

At the same time a catch fixed lower down on H depresses the handle N that opens a valve in the brake pipe M, the effect of which is to apply the brake and to cause the air whistle X to sound until the handle N is again raised by the driver or stoker to the position shown in Fig. 3.

This arrangement of course applies to trains furnished with automatic brakes, and the brake power is regulated by the size of the valve which is opened and shut by N.

When the tappet has cleared the plane BD, the spring L raises the rod H to its normal position, the handle N remaining down until raised by the driver or stoker.

For passenger and goods' trains not furnished with automatic brakes an additional signal to the gong is given by the arrangement shown in Fig. 4.

The handle N in its descent is made to form an electric circuit by pressing O against P, two pieces of brass, working on pivots, to which are attached the wires connected with the battery enclosed in the box R, and so long as the handle N is not put back, an electric bell, which may easily be placed in front of the driver near the steam gauge on the locomotive continues to ring, and must necessarily attract the driver's attention even should he by any unlikely chance have failed to hear the blow on the gong. The points of contact can be boxed over as shown by the dotted lines in Fig. 4. The plan shown in Fig. 4 is one out of numerous ways in which the contact may be formed.

In Fig. 5 a very simple arrangement is shown by which the signalman instantly knows whether his signal is at " Danger " or " Clear."

B is a box let into the ground, in which the stud C works. When A is in a horizontal position, as shown in the Fig., the spring forces out the stud C, and the contact is broken at D but when A is vertical the counterpoise presses on C, which completes the circuit with the cabin at D, by pressing one piece of brass against the other, the two brasses being attached to pivots round which the wires EE are fastened, and causes the red disc for " danger " to show on the indicator in the cabin.

For the automatic test of the various apparatus on the departure of the train, all that is necessary is to have a swinging arm similar to A, Fig. 5, but with a much lighter counterpoise, fixed between the departure rails at the terminus. This arm has no chain or wire connected with it, and always remains in a vertical position, except in the case of a train or engine backing into the station, at which time it falls into a horizontal position by the contact of the tappet under the tender. On the departure of the train, however, it remains vertical and causes the gong to be struck and the brake or electric apparatus to be tested.

The swinging arm and the plane are boxed over as shown by the dotted lines in Fig. 2 ; a slot being made in the covering so as to allow free play of the arm and the tilting plane.

LONG SPAN BRIDGES AND VIADUCTS, IN IRON, STONE, BRICK, AND TIMBER.

(*Continued from page* 309.)

AT Fig. 22 is shown a side elevation of part of the top flange of a triangular girder at its connection with a tie and strut; *a* is the top flange, *b* one side bar of the tie—there being another one of the same size on the further side of the flange, *c* is the strut

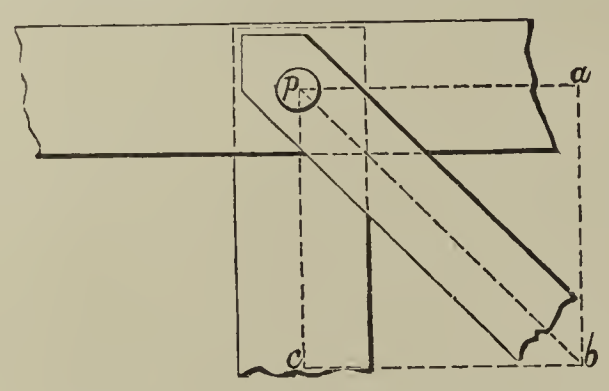


FIG. 22.

passing up inside the flange, and *p* the pin by which the joint is made. Let us assume that each bar of the tie *b* carries a strain of 40 tons, and in addition to the strain thus brought upon the strut *c* let there be an increment of load of 30 tons accruing at the joint under consideration, the load being carried on the top flange of the girder. The tie being fixed at an angle of 45 degrees to the horizon the strain on the *b* will be resolved into equal ones on *a* and *c* each being equal to 40 tons multiplied by the ratio of a side of a square to its diagonal, the parallelogram of forces being as shown by the dotted lines drawn between the letters *a b c p*, in which *p b* represents the strain on *b* and *p a*, *p c*, those due to it on the flange and the strut respectively—the value of *p a* and of *p c* will therefore be:—

$40 \times \frac{1}{\sqrt{2}} = 40 \times \cdot 707 = 28 \cdot 28$ tons, from each bar *b*. The total compression on the strut will be $30 + 28 \cdot 28 + 28 \cdot 28 = 86 \cdot 56$ tons, which at a working strain of 3 tons per sectional square inch, gives an area of $\frac{86.56}{3} = 28 \cdot 85$ square inches, of this strain 56·56 tons is brought on through the pin and the tie bars, and 30 tons through the pin from the flange on which the load rests.

Let us now examine the strain at each *shearing* section of the pin, premising that the working resistance of wrought iron to shearing strain is 5 tons per sectional square inch. On the section in the plane of contact beteen the bar *b* and the side of the flange the shearing strain is evidently that upon one bar *b*, viz., 40 tons, requiring therefore an area of eight square inches which corresponds to a diameter of 2.52 inches. The strain on the next section, in the plane of contact of the strut with the inside of the flange, will be $28 \cdot 28 + \frac{30}{2} = 43 \cdot 28$ tons, requiring an area of 8·65 square inches, corresponding to a diameter of 3·31 inches.

Of these two strains the first *may* be made a simple shearing strain as there is no difficulty in bringing the bar *b* tightly up against the side *a* of the flange, but the second occurs at a distance from *b* being on the other side of the plate forming the side of the flange, so that the resultant stress upon *c* accruing from *b* will be transverse in character.

The moment of resistance of a cylinder to transverse strain is found from the formula $M = S r^3 \times \cdot 785$ where S = direct resistance = 5 tons per square inch, and r = radius in inches. Therefore, $r = \sqrt[3]{\frac{M}{\cdot 785\ S}}$

Let the side plate *a* be $\frac{3}{4}$ inch thick and the bar *b* one inch thick, then taking the force from *b* as acting at the centre of its thickness, its mean distance from the section on the plane of contact of the strut and flange plate will be $\frac{1}{2} + \frac{3}{4} = 1.25$ inches, and the moment of bending strain will be:—$M = 28 \cdot 28 \times 1 \cdot 25 = 35 \cdot 35$ inch tons; requiring a diameter of pin as follows:—

$r = \sqrt[3]{\frac{35 \cdot 35}{\cdot 785 \times 5}} = 2 \cdot 08$ inches radius $= 4 \cdot 16$ inches diameter.

In dealing with the question of torsion practically, it must be regarded as an accident, to be provided against by using metal of a considerable range of elasticity, sufficient to allow of the pins being twisted through any angle that may occur on the deflection of the bridge without producing any permanent set.

We will apply this to the first section of the pin in the example previously taken. In the first place we have 40 tons on the tie bar *b* Fig. 22, and this will demand a bearing surface of 8 inches, in section of the pin pressed upon by the tie bar, this area will be equal to the diameter of the pin multiplied by the thickness of the bar bearing upon it. It is evident, then, that the bar must be thickened at the end where it bears upon the pin; let it be made two inches thick, and the pin 4 inches in diameter, and, see how this will suit for bending strain. The end of the pin acting as a cantilever will have an effective length of 2 inches (the side

plate of the flange must of course be thickened by rivetting a plate on it to give sufficient bearing there) hence the bending moment would be $40 \times 2 = 80$ inch tons, the size of pin required will therefore be

$$r = \sqrt[3]{\frac{80}{\cdot 785 \times 5}} = \sqrt[3]{20\cdot 38} = 2\cdot 732 \text{ in., } \therefore \text{ diam.} = 5\cdot 464 \text{ in.}$$

It is evident here there is more bearing surface than is required, so that can be reduced by fixing less thickness for the bar and this again will reduce the bending moment.

A formula is now required by which may be determined the relation between the thickness of plate and diameter of pin and their respective dimensions settled. The value of S is the same in both cases, viz., 5 tons per sectional square inch, Let W=load in tons; r=radius of pin in inches t= thickness of bar in inches.

$$r = \sqrt[3]{\frac{M}{\cdot 785\ S}} \quad \therefore\ r^3 = \frac{M}{\cdot 785\ S} \quad \text{But } M = W \times t \text{ and } W =$$

$$2\ r\ t\ S \quad \therefore \quad r^3 = \frac{2\ r\ t^2 S}{\cdot 785\ S}\ ;\ r^2 = \frac{2\ t^2}{\cdot 785} \quad \therefore \quad r = 1\cdot 59t.$$

In the equation $W = 2\ r\ t\ S$ replace r by its value, then W

$$= 2 \times 1\cdot 59 t^2 S \text{ and } t = \sqrt{\frac{W}{3\cdot 18\ S}}$$

Applying these formula to the example the following results are obtained.

$$t = \sqrt{\frac{W}{3\cdot 18\ S}} = \sqrt{\frac{40}{3\cdot 18 \times 5}} = 1\cdot 58 \text{ inches.} \quad r = 1.59t =$$

$1\cdot 59 \times 1.58 = 2\cdot 51$ inches, the diameter will therefore be $5\cdot 02$ inches.

Let us see how these proportions work out. First $5.02 \times 1.58 = 7.93$ in. practically correct for the 8 square in. required for bearing. The moment of strain will now be

$$40 \times 1.58 = 63.2 \text{ in. tons, requiring a radius, } r = \sqrt[3]{\frac{63.2}{\cdot 785 \times 5}}$$

$= 2\cdot 52$ inches, the radius obtained above being $2\cdot 51$ inches, practically the same.

It may be advisable to state these as standard formulæ for general use with different values for S.

Let S=working compression in tons per sectional sq. in., and S'=the maximum longitudinal strain on a fibre (or the modulus of rupture). Then

$$r^2 = \frac{2t^2 S}{\cdot 785\ S'}\ :\ r = 1\cdot 59t\sqrt{\frac{S}{S'}} = 1\cdot 59\sqrt{\frac{W}{3\cdot 18\ S}}\sqrt{\frac{S}{S'}}$$

$$= 1\cdot 59\sqrt{\frac{W}{3\cdot 18\ S'}} = \cdot 897\sqrt{\frac{W}{S'}} \quad t = \cdot 629 \times r\sqrt{\frac{S'}{S}}$$

These last two expressions will be applicable to any case, and afford a ready method of promptly determining the dimensions required.

When the bars are so arranged that the joint is what is called in double shear the conditions are altered, for the pin acts as a beam loaded at the centre, instead of as a cantilever, and the effective span will, if the bars are in close contact, be equal to twice the thickness of the centre one.

The moment of bending strain will in this case be $M = \frac{W \times 2.t}{4} = \frac{W.t}{2}$ and as before $W = 2.\ r.\ t.\ s$,—hence

$$r^3 = \frac{W.t}{2} \times \frac{1}{\cdot 785.S'} = \frac{2\ r.\ t^2 S}{2 \times .785.S'} = \frac{.^2 S\ r\ t}{\cdot 785.S'}\ ;\ r^2 = \frac{^2.\ S}{\cdot 785 S'}\ ;$$

$$r. \therefore = 1\cdot 128\ t\sqrt{\frac{S}{S'}}$$

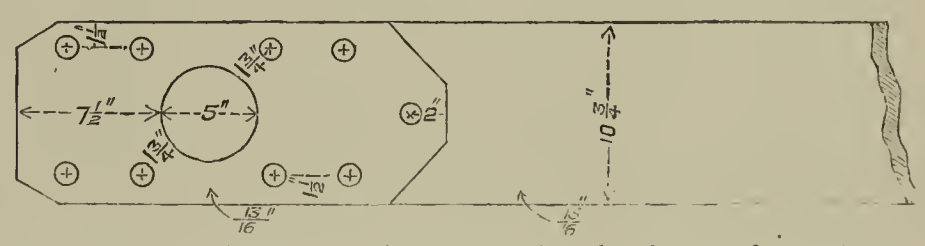
$$\text{But } t = \sqrt{\frac{W}{3.18.S}}. \quad \therefore\ r = 1.128\sqrt{\frac{W}{3.18.S \times}},$$

$$\sqrt{\frac{S}{S'}} = \cdot 632\sqrt{\frac{W}{S'}} \text{ and } t = \cdot 886 \times r\sqrt{\frac{S'}{S}}.$$

It will very frequently happen that it is more convenient to use bars of equal width throughout for ties instead of making them with eyes or swelled ends, then the liners which are rivetted on, or, if preferred, forged on, will serve also to make up the area lost by the pin hole.

In the tie previously dealt with we require an area of 8 sq. in., and we have found that the thickness at the pin hole must be $1\cdot 58$ in., the thickness, practically, will therefore be $1\frac{5}{8}$ in. at that part, this will indicate the *nett* width across the eye of $4\cdot 9$, say 5 in., and adding the diameter of the pin hole the gross width 10 in. is found, the thickness then in the body of the bar will be 13-16 in., and the thickness of the piece to be added 13-16 in. The thickening piece, if rivetted on, must be held by a sufficient number of rivets to give an area equal to its effective area at the pin hole, that is, 4 square inches. Let the rivets be $\frac{3}{4}$ inch diameter, having each $\cdot 44$ square inch sectional area, must be arranged so as to leave a full effective area all through, as shown at Fig. 23. If, however, the rivets then the number required will be $\frac{4}{\cdot 44} = 9$ rivets, which

Fig. 23.



are used, we lose one rivet hole in the body of the bar, which must in that case be therefore made $10\frac{3}{4}$ inches wide. If the thickening piece is welded on the 10 inches will be sufficient. The distance from the pinhole to the end of the bar should be $1\frac{1}{2}$ diameters of the pin.

We will now come back to joints made with rivets in the connection of ties and struts with main girders. Rivets are invariably calculated as for shearing strain, and they are so closely held by the plates that there appears to be no room for bending, and when they do give way it is very probable that they yield by shearing, though when the rivetting is properly executed the contraction of the rivets in cooling will so firmly press the plates together that the friction alone will greatly assist in preventing the plates from slipping. It is useful to estimate what this resistance of friction may amount to,

but in so doing the fall of temperature must be taken from a point below that at which the iron of the rivet body will draw, and in no case can the pressure thus put upon the plates exceed that due to the limiting strain of elasticity of the iron.

At a temperature of 600 degrees Fahrenheit iron is just below that at which it begins to become visible in the dark, and from this point it may be taken to contract as it cools down to, say, 80 degrees.

Now a change of temperature of $13\frac{1}{2}$ degrees in wrought iron corresponds to a strain of one ton per sectional square inch, that is to say, one ton strain per square inch will extend a bar the same amount that it will expand when its temperature is raised $13\frac{1}{2}$ degrees; dividing then the range of temperature cooled through by the $13\frac{1}{2}$ degrees, the theoretical pressure would be obtained. It must, however, be remembered that the hot rivet will cause the iron immediately around it to expand, and although its great mass compared to the rivet will prevent its getting very hot as the heat will be rapidly conducted away, this point must be taken into consideration, but if the difference of temperature between the rivet and the surrounding iron be only 108 degrees, the pressure of cooling will amount to 8 tons per square inch of rivet area, which is the limit of elasticity of the iron, and beyond which the iron would draw.

The ordinary co-efficient of friction for iron upon iron will not apply in this case, as it has been shown by Mr. G. Rennie that under increasing pressures the co-efficient of friction rises very materially, thus at a pressure of 32·5 lbs. per sq. in. it was ·140, at 2 cwt per sq. in. ·271, at 3 cwt ·312, and so forth.

The number of rivets required to hold the end of our tie bar (10 in. × 13-16 in.) will be at $\frac{3}{4}$ in. diameter $\frac{8}{\cdot 44}$ = 19 rivets, which will occupy a space of about 150 sq. in. of plate surface. The total pressure upon this surface at the above calculation will be 8 × 8 × 20 = 1280 cwt, and $\frac{1280}{150} = 8{\cdot}53$ cwt per sq. in.

Rennie found the co-efficient at 5 cwt per sq. in. to be ·409, and about that point it was increasing very slowly, so for our pressure we may safely take ·4, knowing it will be well within the actual quantity. Then having the total pressure on the plates 64 tons, the resistance of friction will be 64 × ·4 = 25·6 tons.

Special conditions in each case will naturally arise which will materially influence the amount of "hold" the rivetted plates get frictionally of each other, but we do not think that it can ever amount to the working strength of the rivets, and the very fact that girders do take permanent set under comparatively small loads when first put up, shows that the plates draw until they take as fair a bearing on the rivets as may be in accordance with the quality of the work. This drawing will probably much reduce the hold the rivet-heads have on the plates, and so the frictional resistance will thus be made of but little value.

Of this source of strength but little account can be taken, because of the uncertainty attending it, if we had any means of ascertaining what really does take place in these joints after they are made it would be different, but as it is, there is only surmise left.

One great use in enquiring carefully into such questions as the above, lies in the hints which may be drawn as to the execution of rivetted work so as to get all the advantages which are within reach.

One source of permanent set in a built structure is the space around a rivet when cold in the holes, for if when the rivetting process is finished the rivet is much hotter than the surrounding iron it will in cooling contract and shrink away from it, and so will *not fill the rivet hole.* This is more likely to occur the more quickly the heading up of the rivets is done, for that gives less time for the iron around the rivet to come more nearly to its temperature, and also the spreading out of the rivet ceases at a much higher temperature than is necessary, therefore in this respect hand rivetting should be superior to power rivetting.

The space around the rivets is of most practical importance in the amount of permanent deflection it permits, for the girders should be so made that when fully loaded they do not deflect below a horizontal line drawn between the extremities of the bottom flanges, otherwise they present an appearance of weakness which it is always desirable to avoid.

If the joints in the compression flange butt truly there will be no giving there, but there will always be the drawing of the joints in the tension flange in such cases.

This set and the deflection proper must be provided for by, in the first place, making the girders with a curve or "camber" upwards, sufficient to include all sets and deflections.

The almost universal practice is to allow a camber or rise of one inch for every forty feet of span; let us see how this fits in with the calculated deflection.

If the girder is so designed that the strains per sectional square inch are uniform throughout, it will deflect in a circular arc, if it be of uniform section throughout it will not, but the former condition will be that which is found in long spans.

Suppose a girder, in the first place, that is made horizontal and has flanges parallel and of equal length, then when a load comes upon it the top flange will be shortened and the bottom extended, the altered lengths giving the lengths of two parallel circular arcs, of which the distance apart is equal to the effective depth of the girder from these data, the radius of curvature and the versine of the arc or deflection of the girder can be readily obtained, the formula working out to the following general form.

Let L = span of girder, d = depth, both in feet, l = difference in length of flanges after deflection, D = maximum deflection, then for a girder supported at both ends,

$$D=\frac{L\times l}{8\times d}$$

The modulus of elasticity must be determined for the particular kind of structure in question, it is evident that that obtained from solid iron will not be right for rivetted work for which we have found, calculating from a number of structures of good average work 6400 tons per sectonal square inch to be about the mean.

The general practice of English engineers keeps the strains on structures well within the Board of Trade allowance, hence if that be taken the outside deflection will be obtained. Working upon these figures we find,

$$l=2\left\{L\times\frac{5}{6400}\right\}=\frac{L}{640}$$

$$D=\frac{L\times l}{8\times d}=\frac{L}{8\times d}\times\frac{L}{640}=\frac{L^2}{5120\times d}$$

If d be one-tenth the span, this gives $D=\frac{L}{512}$, or one inch for every 42 feet 8 inches; this certainly does not allow much for permanent set due to rivets taking their bearings, and if it is wished the girder shall not deflect below the horizontal line, a camber of one inch in thirty feet should be given, if there is any chance of working up to five tons strain, but where it is kept down (as it generally is) below four tons, the maximum deflection will not exceed one inch in 53 feet 4 inches for the same ratio of depth to span, or 44 feet 5½ inches for the ratio of one-twelfth. Even here it is very seldom that the maximum strain will be reached, as it is always calculated for a string of the heaviest engines and tenders, so for general work the camber usually adopted may suffice. We may here digress for a moment to point out what appears a strange inconsistency in the Board of Trade allowances, it is that with 5 tons allowed per inch, the deflection allowed in inspection is one inch per 100 feet of span. Now, with the best rivetted work, 10,000 tons is the highest modulus shown, and this would give one inch in 66 feet 8 inches.

This deflection allowance, however, refers to live load only, so it may not come so far off, but taking the former modulus found from average work and from the total deflection, deducting that due to dead load (the dead load being as previously ascertained 1·69 tons per lineal foot to 1·5 tons per lineal foot of live load), the deflection becomes 1·1 inches per 100 feet, so that after all the deflection test thus used is of no use in estimating the actual stability of the work being inspected.

The next point to be considered is, how the camber is to be given to the girder in the course of manufacture.

First, let us state emphatically how it should *not* be done, that is by "doing it in the rivetting," which means simply putting the girders together on a blocking or stage to which the required camber is given, drifting the holes out where they do not fall fair, and so rivetting the work up; the camber then depends evidently upon defective or inaccurate rivetting, and cannot, therefore, be relied upon.

The respective lengths (corresponding to the required camber) of the top and bottom flanges should be calculated, thus:—First find the radius of curvature from the formula $r=\frac{l^2}{8v}+\frac{v}{2}$ where r = radius, l = span and v = camber or versine, then the additional length required in the top flange for a parallel girder will be $l'=\frac{l\times d}{r}$; l' being the additional length and d the effective depth of the girder.

The camber v being very small the quantity $\frac{v}{2}$ may be neglected in the formula which may then be consolidated into $l'=\frac{8vd}{l}$, the length and depth being taken in feet and the camber in inches will give the additional length in inches.

For a 300 feet span, at one inch per 40 feet. 7½ inches would be required, then the additional length in the top member will be, if d, = 30 feet

$$l'=\frac{8vd}{l}=\frac{8\times 7{\cdot}5\times 30}{300}=6 \text{ inches}$$

and if the girder be made in ten bays, the bottom pins being 30 feet from centre to centre, the top ones should be 30 feet 0·6 inches from centre to centre, and the pitch of rivets must be widened out in the top to suit this. If the rivets are four inches pitch there will be in the bottom member for each bay 90 rivets in 30 feet, and in the top the same number of rivets in 30 feet 0·6 inches, and, although the pitch does not admit of being conveniently stated, there is no difficulty in dividing up the given length into the required number of pitches.

Strictly speaking, the bottom edge of the top flange should be shorter than its top edge, and the same remark applies to the bottom flange, and if the flanges be 3 feet in depth this difference per bay will be 0·06 inches, but it is not often that this is attended to in practice as the flanges are commonly too shallow to show any appreciable difference in the top and bottom lengths; however, in such large works as those of which we are treating, these points must not be overlooked, and the proper bevel must be given to the ends of the side plates where they join or they will not properly butt together.

In plate girders, the web plates must be cut taper according to the camber, and the work, in fact, executed in all cases in such a manner that when the girder is rivetted up it has its proper camber without any internal strain having been brought upon any part of the work.

Where the camber is not given, but instructions to give sufficient according to the judgment of the manufacturer, the additional length for the top flange may be calculated from the direct strain. Ascertain the strain per square inch to which the girder has been calculated, multiply the span by twice that quantity, and divide by the modulus of elasticity, this gives the sum of, the lengthening of the

bottom and shortening of the top flanges under a full load, and is, therefore, the excess required in the top flange when there is no load on.

We will now consider the arrangement of viaducts having a number of consecutive spans:—The first point to be settled is whether continuous or discontinuous girders should be used.

In a previous part of these articles (p. 173) we showed that the use of continuous girders would be attended by a saving of 7·59 per cent. theoretically on the flanges. On the theoretical consideration that in a perfectly designed girder the weight of the web will equal that of the two flanges, the saving on the whole superstructure should be 3·97, nearly 3·8 per cent., and this is a considerable amount in heavy works.

Of course if the viaduct is on a curve it cannot be made continuous consistently with the correct principles of construction.

For many reasons curved viaducts should where possible be avoided, not only on this account, but because also elements of unsafety are introduced; the distribution of the strains laterally is constantly varying, for the rails must be laid on a curve, and the girders must be made straight, hence the position of the centre of gravity between the girders will be constantly varying as the load moves on, tending to give rise to a rocking motion of the whole superstructure, and the pressure of the train against the rails due to its centrifugal force will also have a tendency to displace the girders laterally on their bearings.

In very long continuous girder viaducts some inconvenience may arise from the expansion and contraction, which in the English climate amounts to 1 in. for every 150 ft. of span, between the extremes of summer and winter, this would be 8 in. for a 1,200 ft. length. Such length would correspond to a total viaduct length of 2,400 feet, for the girders would be made with a fixed bearing on the centre pier and allowed to expand and contract in each direction towards the abutments. The difficulty arising from a large amount of expansion is in the arrangement of the platform joints at the ends, as these must be arranged on a telescopic principle, and so that on opening out the ballast shall not get in and jam in the joint. If an iron floor be used, flap plates can be formed at each end with their outer edges resting on bed plates fixed on the masonry of the abutments. Then when the girders expand, these flap plates will, as it were, shovel the ballast back on to the abutment, and on the contraction of the girders let it again settle down to its former place.

To avoid having to provide for so great an amount of expansion at one joint the girders may be divided into a number of shorter lengths, running to 500 or 600 feet each without altogether losing the advantages accruing from the adoption of continuous girders, but there is one awkward point arising where this course is pursued, in reference to the appearance of the structure, for although it looks wel enough with a short span at each end, yet the introduction of short spans in the general run of the viaduct will tend to an unsightly effect, and we have seen that when a number of consecutive spans are continuous the end spans should be about four-fifths of the central spans, this length corresponding to the mean position of a joint of contrary flexure, and therefore the most suitable for obtaining a proper distribution of the strains throughout the whole length of the girders.

We may here mention that continuous girders should be made straight or with only sufficient camber to be taken out by the weight of the *dead load* as the direction of curvature of flanges is not the same throughout.

From our previous investigations it appears that there is no practical gain in using continuous girders of two spans, so that whether we do so or not is of no moment, and will be decided by matters of convenience of fixing, thus if we make the girders discontinuous there will be two bed plates to fit on each pier, whereas ifthey are in lengths of two spans continuous, only one bearing will be required on the alternate piers.

In designing the superstructure the struts and ties should be placed in the position which offers the least resistance to the wind, and in order to reduce this to a minimum a braced or lattice work form of strut may be advantageously introduced in place of using a H section built up of plates.

The use of continuous girders affords great facilities for erection, as they can be conveniently erected on one side of the site of the viaduct and rolled into position, but as we are touching upon the question of erection it is convenient here to enter into the matter at length, for the mode and means of erection of any structure ought to be decided upon before the completion of the general design, much trouble, delay, and loss, frequently arising from deferring the consideration of this question until the work is approaching completion in the iron yard.

The question of locality will greatly influence the character of pier adopted, and of course through the piers will lead to modifications of superstructure also. If we have a perfectly sound bottom to build upon we shall of course be at perfect liberty to adopt any material that is cheapest for our work, and probably iron will be altogether discarded where stone is plentiful, as viaducts of this latter material are more stable and more durable than those erected in iron; but the soil and substratum may be of such a quality as not to be relied upon to carry a stone viaduct, but yet may do for stone piers and an iron superstructure, while a yet worse foundation may necessitate the use of a structure altogether iron; as far as the erection of the masonry piers is concerned, we leave dealing with that until we reach the part of our articles to which it properly belongs, and we therefore have here to devote our attention solely to the erection of a viaduct entirely constructed of iron, which possesses the great advantage of lightness, rendering it suitable to weak foundations.

In districts where mining operations are being or have at any past time been carried on, the foundations must be very carefully examined before commencing the erection of the viaduct, and where old workings exist on the site of the proposed structure they must be solidly built up under each intended pier, and to some distance on each side, to afford a safe basis for the superincumbent load to be placed upon them.

Some idea may here be given of the load to be carried by various materials acting as foundations. The late Professor Rankine gave quantities as follows, for working load:—rock, hard as red brick, 9 tons per sq. ft.; good concrete, 3 tons per sq. ft.; soft rock, 1·8 tons per sq. ft., and hard clay, 1 to 1·5 tons per sq. ft. These quantities are merely fancy ones, as the working loads found in practice very greatly exceed them. For instance, take the Victoria Tower at Westminster, and other similar structures whose ultimate foundation is on London clay, loaded with 4 tons per superficial foot, and certain viaducts and large bridges in the north of England which have come under our own notice, which resting on blue and grey shale have working loads of 9 tons, 10 tons, and even upwards of 11 tons per foot; but in these cases the foundations are of course carried down to a considerable depth, so that the bearing stratum is laterally confined and so prevented from squeezing out or upwards.

Having ascertained the nature of the strata in which we have to work, the form of the lowest part of the pier may be derermined. If there is strong clay or shale, screw piles may be used, in which case the piles themselves should be hollow, so as to allow of their being screwed down with facility, then when the necessary depth is reached the piles can be filled up with concrete, so as to give a full bearing all over the surface enclosed by the periphery of the screw-blade.

If, however, the strata passed through contain large stones or rock boulders, obstacles to driving the screw piles almost prohibitive will occur, then some other kind of foundation must be used. In such a case the columns, if small, may be grouped upon a masonry or concrete bed, and this will have the further advantage of distributing the load and reducing the pressure per square foot upon the subsoil.

Where the ground is of a heterogeneous character there would be, with screw piles, danger of some of them sinking more than others and so becoming useless in sustaining the superstructure, and causing also undue wrenching strains upon it, and upon the pier bracing well; in such a case it is absolutely necessary to have a very solid base to the pier, which may so carry and distribute the weight upon it that the inequalities beneath shall not affect the superstructure. If the base is made of concrete the bottoms of the piles will be embedded in it, and so securely held, but if masonry is used the bottoms of the pier columns must be held down by anchor bolts passing right through the masonry and secured to anchor plates beneath it. The holding down bolts must of course be placed in the foundation, and the masonry built up round them, sufficient play being allowed for their adjustment to the base castings of the pier columns, but when the masonry is carried up to the required height, and the position of the bolts determined, cement is to be poured into the spaces around the holding down bolts, in order that they may be steadily held and prevented from working loose by vibration.

The base castings being in position, but not screwed tightly down, the first or bottom tier of columns is to be erected upon them and properly secured by the cross bracing, after which the nuts on the holding down bolts are to be tightened down and the ends of the bolts rivetted over them, thus the whole weight of the foundation is so secured to the pier as to serve, by its stability, to largely assist in resisting wind pressure; in point of fact such a foundation properly set in the ground will be so permanent that the stability afforded to the pier above will be limited only by the strength of the holding down bolts.

The bottom tier of columns having been secured will afford hold for such scaffolding as is necessary to the erection of the second tier, and so on each tier that is fixed acts as a scaffolding upon which to raise that above until the top is reached, and the bearing girders (upon which the main girders are destined to rest) are fixed in position, ready to receive the superstructure.

The greatest care must be used in setting out the foundations and in levelling and fixing the base castings and lowest tier of columns; these once properly arranged it follows that the work above, assuming that it has been accurately made in the iron yard, must as a matter of course come together correctly.

Assuming now that all the piers are complete we can proceed to carry out the arrangements made for the placing in position of the superstructure.

(*To be Continued.*)

ERRATUM—Two clerical errors occurred in October issue, by one, page 261, col. 2, lines 2 and 3, the loads on the diagonals were halved, a half base instead of a whole triangle base being taken; by the other the factor for length of diagonals was used, page 262, col. 2, line 18, instead of that for the weight of iron per square inch per foot of length, the result showing that the total weights, page 263, should be 305·46 tons instead of 150·67 tons.

RAILWAYS IN INDIA.

No. 1. Their History for the past Seven Years. Guaranteed, State, Productive, Protective and Provincial Lines.

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BLUE BOOKS are proverbially the driest of reading, but proverbs, like rules, are open to occasional exception, and one must be allowed in favour of those on Railways in India, compiled by Mr. Juland Danvers, Government Director of the Indian Railway Companies, and Secretary of Public Works Department, India Office. Inasmuch as Mr. Danvers has now furnished no less than twenty-two annual reports, it is needless to say that he is master of his subject, and we may add that he has treated it on each occasion with a graphic power that sustains the reader's interest throughout. The subject, indeed, is one that requires the highest qualities, intellectual and otherwise, on the part of its exponent; for those who have not studied it will discover as they peruse these pages how great and diverse are the interests involved, and how immense the difficulties of many kinds with which those who are endeavouring to create an adequate Railway System in India have to contend. We learn with regret that the report for 1881-2 is Mr. Danvers' last, and it is not surprising that an inflexion of regret is to be detected in the sentences with which he takes farewell. A man who has occupied twenty-two years in one department of his country's service, under whose direction nine thousand miles of railway have been created, and who has had the administration of the expenditure of a hundred millions sterling, may well feel the wrench of quitting the sphere of his priceless services. The annual review of Railway proceedings in India is in future to be prepared by Government Officers in that country. The Indian Government is well served, and we do not doubt that the reports of the future will be adequate to the importance of the occasion, but the most brilliant civilian to whom the task may be entrusted will never be able to improve upon the terse, lucid and comprehensive method of the gentleman who now retires.

At the close of the year 1875, there were completed in India, 6,497¼ miles of railway, 261¼ miles having been added during the year. At this period, Mr. Danvers paid an official visit to that country, and embodied the results of his inspection in a separate report to the Secretary of State. This able paper affords a convenient point of departure, being an authentic record of the state of things then existing, and enabling us to judge with accuracy of the comparative progress of after years. Mr. Danvers commenced by pointing out that "within the time which forty years ago it would have taken to communicate by letter between London and Calcutta we were able to go to India and back and to traverse the length and breadth of the land, from Tuticorin and Beypore in the South, to Multar and Jhelum in the North; visiting on our way most of the important cities, including Madura, Trichinopoli, Bangalore, Hyderabad, Poonah, Ahmedabad, Baroda, Jabalpur, Benares, Allahabad, Cawnpur, Lucknow, Agra, Delhi, Ajmere and Lahore; remaining several days at Calcutta, Madras and Bombay; stopping to view the new and rising industries of the country, such as the coal mines of Wurrora, Mopani and Kurhurballi, the iron works of Raneegunge and the factories of Bombay, Surat, Broach and Calcutta; and mounting several hill stations and Sanatoriums." But Mr. Danvers further showed that speedy communication was a small part of the work that railways were accomplishing. He says, "they are producing a most important and beneficial influence over the moral and material interests of the people; and they are furnishing those who are responsible for the government of the country with the most effectual means of establishing peace and security." The condition of the lines was pronounced to be generally good. Mistakes and failures have necessarily arisen in the construction of so vast a system, but these are allowed to have been inseparable from great operations of a novel character in an unknown country. "Taking the railway system of India as a whole, it cannot but be regarded as a triumph of human industry and skill." The character of the work done by the Civil Engineer is thus described:—"He had to contend against the forces of nature to a far greater extent than is the case in this island. He had to overcome the difficulties which the gigantic features of the country placed in his way; he had often only poor materials and inferior labour at his command, and he had to meet the dangers of exposure to a burning sun by day and malarious vapours by night. To his skill and professional knowledge he accordingly had to bring more than ordinary courage and endurance. Many broke down, but their places were immediately filled by others, and the result is exhibited in the thousands of miles of railway which thread their way over mountain passes, cut through thick jungle and span huge and uncertain rivers." In all departments, Mr. Danvers observed a corresponding energy. The station accommodation was found to be almost too good, except in certain cases where its acknowledged insufficiency was in course of improvement, and a noticeable feature on the lines in Upper India was that the stations were so constructed that they could easily be

fortified in case of need. The locomotive stock provided was in most cases excessive, while the power of the engines was often inadequate. "The adhesion in India is usually good, and it seems to be generally held that a larger sized cylinder than we are accustomed to use in this country may be utilized there: also that good types would be, for passenger and mixed trains, four-wheel couple engines with 5′6″ wheels and cylinders 17″ diameter and 24″ stroke, and, for goods, six-wheel coupled with cylinders 17″ × 24″, the wheels being 4′6″ in diameter for goods trains, each pair of wheels having about 11 tons upon them."

The Indian Railways are constructed some on the four feet, some on the five feet six inches, and some on the metre gauge. Mr. Danvers found the travelling on the latter as smooth and steady as on the broader guage, and discerned no difference in the comfort and ease of travelling. This description of railway had not been long enough open to enable a reliable conclusion to be arrived at with regard to its cost of working as compared with broader guage lines; and the cost of transferring goods from one line to another, its inconvenience and the diminished facilities of transport caused thereby, made it a question how far these breaks of guage should be permitted. Light and cheap railways are recommended for certain districts where there are yet not even metalled roads, and the experiment is now being tried. Most strongly does Mr. Danvers advocate the policy of low prices. He describes how in some places his train passed through fertile valleys where the surface of the ground presented, as far as the eye could reach, one large, unbroken sea of rice or corn, while in other parts the cultivable area might be increased were it connected with a market. Thus opportunities for obtaining traffic are not wanting, but, to make railways as serviceable and profitable as they should be, they must be brought within reach of the people, who soon become alive to their value. This is proved by the fact that on some lines, where the passenger rates have been reduced to from one farthing to the third of a penny per mile, the natives absolutely give up their caste in order to save their pence, the high caste travelling with his lower caste brother rather than pay a higher fare. Probably, to those who understand what this means, the civilizing influence of railways in India will require no higher testimony.

The relative character and value of European and Native labour on Indian Railways is both interesting and suggestive. While the former are employed as superintendents, locomotive foremen, drivers, and so forth, the work in the shops is principally performed by natives, whose wages are in about the proportion of annas to rupees (one-sixteenth) compared with Europeans. The swarthy arms of stalwart natives deal blows worthy of English strikers at the forge, and the nimble fingers of mere children, directed by sharp eyes, may be seen manipulating minute parts of machinery. Natives are also being gradually trained to manage the locomotive. Many of them fill the positions of station masters, clerks, and assistants to traffic managers, as well as accountants and guards. Having referred to the prospects of the native coal fields and the hopes regarding the manufacture of iron, a description is given of some highly successful experiments made under a military committee, to see how railways in India could best be made available for military use, and Mr. Danvers summarises his conclusions thus:—That the railways are conferring immense benefits on the country: that they are upon the whole in good condition, and carefully managed: that they may do more than has hitherto been done for the development of traffic, and for the increase of profits: that a decrease in the rates of some of the present charges for conveyance, and an increase of facilities would assist to accomplish these objects: that measures of this description have been and are still being taken: that close attention is required to the expenses of working and maintenance in order to secure economy: that the extension of the present system, and the construction of light feeders is much to be desired, whenever the state of the finances of the country admits of the necessary expenditure.

The general summary was as follows:—1875.—During the year 261 miles were added to the open system of Indian railways, bringing the whole extent completed up to 6,497 miles, of which 768 are constructed with a double, and 5,729 with a single line: 5,676 are on the 5′6″ guage, and 821 on the narrow guage. Authority has been given to take in hand railways which, in addition to the lines already executed, will bring the whole length of railway up to 9,415 miles.

During the year, 288,186 tons of railway materials were despatched to India from this country, of which 124,192 consisted of fuel. Since the commencement of railway operations there, 5,181,724 tons of goods, of the value of 34,659,444*l.* have been shipped in 8,495 ships.

The proprietors of stock and debentures of the guaranteed lines number 62,608, of whom only 390 are natives residing in India. The proportion of stock held in India is 1·56 per cent. of the whole.

The total amount expended on the railways to the 31st March last was 105,790,929*l.*, of which 93,720,794*l.* consisted of guaranteed capital, and 12,070,135*l.* of funds raised direct by the Government. Last year 2,760,940*l.* was expended on State lines, and 1,279,000*l.* on guaranteed lines.

The revenue derived from the open lines was 3,647,868*l.* The gross receipts were 7,412,179*l.*, and the expenditure 3,764,311*l.* The passengers earned 2,459,043*l.*, goods 4,703,509*l.*, and miscellaneous receipts amounted to 249,527*l.* The sums advanced to the different companies for guaranteed interest amounted to 4,650,346*l.* which was 1,073,832*l.* more than they yielded.

The number of passengers carried was 26,779,437, being 2,498,978 more than the previous year. The proportion

per cent. of the first class was 0·78, of the second 2·30, and of the lower classes 96·92. The number of tons carried was 4,388,649. The proportion per cent. of the gross revenue from goods was 65·67, and from passengers 34·33. The number of miles travelled by trains was 17,950,312, compared with 18,475,322 of 1874.

The expenses of maintaining and working the railways amounted to 3,764,311*l.* compared with 3,841,522*l.* of the previous year. This outlay is, in several cases, augmented by the heavy cost of repairs in consequence of the damage done by floods. But one great source of ordinary expenditure is the large amount of tare, arising partly from the construction of the vehicles, and partly from the unequal stream of traffic up and down the lines.

1876.—At the close of this year 6,937 miles of railway were open, of which 479 were completed during the year. 767 miles were laid with a double line, 5,748 were constructed on the 5 feet 6 inch gauge and 1,162 on the metre gauge.

The total amount expended on the railways to the 31st March, 1877, as regards the Guaranteed lines, and to the 31st December, 1876, as regards the State lines, was 109,364,867*l.*, of which 94,272,265*l.* consisted of guaranteed capital, and 15,092,602*l.* was raised by the Government for the State lines. During the year 1876 about 3,500,000*l.* was expended on the State, and 879,665*l.* on the Guaranteed lines. The revenue derived from the railways during the year was 4,564,823*l.*, of which 4,451,422*l.* was earned by the Guaranteed Companies. The amount advanced for guaranteed interest to these Companies was 4,634,222*l.*, leaving a difference of 182,800*l.*, but 811,334*l.* of the revenue consisted of surplus profits from certain lines, half of which had consequently to be returned to the Companies.

The gross receipts were 8,793,982*l.*, and the working expenses 4,229,156*l.* The receipts from passengers amounted to 2,646,570*l.*, from goods 5,655,238*l.*, and from miscellaneous sources 483,232*l.* Compared with the previous year, the revenue showed an improvement of 916,955*l.*, and instead of having to supply a net sum of 1,073,882*l.* for guaranteed interest, the Government had only to provide 588,467*l.*

The number of passengers carried was 30,535,319, with an average mileage open of 6,592 miles compared with 26,779,437 of the previous year, and a mileage of 6,298. The proportion per cent. of the first class was ·76, of the second 2·24, and of the lower classes 97·. The amount of goods carried was 5,871,690 tons, compared with 4,388,660 of 1875. The proportion per cent. of the gross revenue from passengers was 33·84. and from merchandise, including minerals, 66·16.

The expenses of maintaining and working the railways were 4,226,966*l.*, being 487,043*l.* more than the previous year, and 49·20 per cent. of the gross receipts. The East Indian Main line came to only 34 per cent., the Eastern Bengal, 46·55, the Great Indian Peninsula, 47, while the Scinde, Punjab, and Delhi, were 67·35, the Madras 64·38, and the Oude and Rohilkund 63.94 per cent.

The marked progress here apparent was justly attributed by Mr. Danvers in a great measure to the adoption of more liberal principles of management, and the enforcement of a rigid but wise economy. On some lines passengers were carried for less than a farthing a mile, and rates as low as a halfpenny per ton per mile were charged, with good effect for the carriage of grain, seeds, coal, and other staple products. But there was another important factor. The valleys of the Ganges, Jumna, and Indus were developing into a granary for England. In the year 1871 the exports of wheat and oil seeds were 248,522 cwt. and 3,382,447 cwt. respectively, of which 1,384,023 was sent to England. In 1876 the wheat exported amounted to 5,583,336 cwt., of which 4,337,208 came to this country, and the seeds to 5,614,817 cwt., of which 3,740,362 came to England. Five years before, the aggregate quantities of these articles carried on the different railways then open were 7,460,340 cwt. of grain, and 2,672,640 cwt. of seeds; in 1876 they were 25,640,720 cwt., and 11,862,262 cwt., being a total of 37,502,982 cwt., or 1,875,149 tons. So long as the difference between the price in the English market, and the united cost of production, inland transit and freight, left a fair margin of profit to the producer and merchant, Indian wheat would find its way to England. The railways were already enabling this to be done, and it was confidently expected that the export of this would largely increase, and other products of the soil be added to it. To how great, almost marvellous an extent this expectation has been realized, subsequent pages will show.

1877.—During this year 492¾ miles were completed, and 225 after the close of the year. There were 806½ miles laid with a double line; 5912¾ were constructed on the 5 ft. 6 in. guage, and 1,638¾ on narrower guages. The capital outlay on the State lines amounted to 3,122,051*l.*, and on the Guaranteed lines to 1,374,882*l.*, bringing the total expenditure up to the end of the year in round numbers to 113,344,500*l.*

The revenue derived from all the open lines during the year was 6,232,888*l.*, of which 6,091,532*l.* was earned by the Guaranteed lines, with a capital of 95,482,941*l.*, and 141,356*l.* by the State lines, on a capital expenditure of 17,661,600*l.* The net receipts from the Guaranteed lines exceeded the amount advanced for guaranteed interest by 1,454,591*l.*; the year before there was a deficit of 216,517*l.* The average receipts per cent. for the year were 5*l.* 5*s.*; the maximum earned was 9*l.* per cent., by the East Indian. The Eastern Bengal yielded 8*l.*, the Great Indian Peninsula 6*l.* 10*s.*, and the Bombay Baroda, and Central India 5*l.* 6*s.* 4*d.* per cent. per annum.

During this year large receipts were obtained at a less proportionate expenditure than in any previous year, The aggregate earnings were 11,236,121*l.*, and the working expenses 5,003,233*l.*, being an average of 44 per cent. of

the gross receipts. The receipts from passengers were 2,844,000*l.*, from goods 7,675,414*l.*, and from miscellaneous sources 716,707*l.* Compared with the previous year the net revenue showed an improvement of 1,686,914*l.* The expenses of the East Indian (main line) were only 31 per cent. of the gross receipts. Those of the Eastern Bengal 41, of the Great Indian Peninsular 48, of the Madras 59. The number of passengers carried was 34,143,512, with an average mileage open of 7,021¾ miles, compared with 30,535, of the previous year, with a mileage of 6,694. The proportion per cent. of the first-class was ·63, of the second 2·23, and of the lower classes 97·14. The weight of goods carried amounted to 8,309,943 tons, compared with 5,794,949 of the previous year. The proportion per cent. of the gross revenue from passengers was 25·77, and from merchandise, including minerals, 69·37.

The operations of this year were marked by the important part played by railways in connection with the famine. There was scarcity in the south, and plenty in the north, which led to large quantities of grain being forwarded from one end of the country to the other. The receipts from this source were a substantial set-off to the heavy charges incurred by the Government in the relief of famine, and the railways were instrumental not only in alleviating distress and preserving life, but in reducing expenditure. But the receipts from the famine traffic were realized at the expense of other and more profitable traffic which was excluded through an insufficiency of rolling stock. The export trade in articles brought down by the railways to the coast exhibited an astonishing increase as compared with the previous years.

1878.—An additional length of 995¼ miles were added during the year making a total distance of 8,215 miles on which traffic was being conducted at its close. The military value of the railways was proved during the Afghan campaign, four thousand men of all arms being conveyed daily, in properly arranged proportions, from Delhi to Lahore, for many days together. By this means 146,000 troops and followers, 15,197 horses, ponies and mules, 6,227 bullocks, 218 camels, 138 guns and 33,780 tons of commissariat and other stores were transported in 184 special trains during the operations.

Railway materials to the amount of 215,043 tons, at a cost, including freight. of 2,336,599*l.*, were shipped to India during the year; and besides this, 125,899 tons of coal, 1,326 tons of coke, and 6,874 tons of patent fuel, at a cost of 221,553*l.*, including freight. Since the commencement of railway operations in India, 6,286,146 tons of goods, which, inclusive of freight, cost 39,363,164*l.*, had been sent from this country.

The total number of holders of Indian railway investments in England and India on the 31st December, 1878, was 64,321. In this country 25,053 held stock to the amount of 1,000*l*, and upwards, 34,960 held stock of less amount, 771 held debenture bonds, and 3,000 debenture stock, while 220 Europeans and 317 Natives were registered shareholders in India.

The capital outlay during the year ending 31st March was 1,294,816*l.*, on the guaranteed lines, and a sum of 3,629,476*l.* had during the year ending the 31st October, 1878, been expended on the State lines. The total amount of capital which had been expended on the former was 96,725,679*l.*, and on the latter 21,291,076*l.* The cost per mile of the broad guage lines in the hands of the Companies (of which about one-seventh have a double track) varied from 20,000*l.* to 10,470*l.*, averaging 17,000*l.* The seven metre guage lines, aggregating 1,600 miles in length, cost, on the average, 7,366*l.* per mile, varying in the case of the Holkar line, with the passage of the Nerbudda and the ascent of the Vindhyas in a length of 86 miles, from 15,000*l.* per mile to the Hathras and Muttra line, laid on an existing road, and 29 miles in length only, 3,620*l.* per mile.

The net revenue derived from the railways during the year 1878 was 5,197,815*l.*, compared with 6,248,469*l.* of the previous year, and 4,564,823*l.* of 1876. The Guaranteed lines earned 5,002,028*l.*, compared with 6,117,326*l.* The amount paid for guaranteed interest in respect of the year 1878 was 4,708,134*l.*, so that there is a surplus profit of 293,894*l.*

The goods traffic of 1878 was not equal to that of the previous year, when it had been inflated by the movement of grain for famine purposes. The export trade in wheat was also large in that year, while in 1878, American wheat was sold in England at 30s. a quarter, and that from India could not be supplied under 40s. The number of passengers increased, being 38,495,473 compared with 34,156,621 in 1877; the gross earnings being 3,143,860*l.* and 2,852,973*l.* respectively. The proportion per cent. of first class was · 651 of second 2·472, of the lower classes 96·877.

The lower classes increased from 33,181,971 to 37,326,358; the second from 763,647 to 951,717; the first from 211,173 to 217,668. The aggregate quantity of merchandise carried was 7,296,335 tons, compared with 8,309,943 in 1877 and 5,794,949 in 1876. The amount received for conveying the same was 6,734,059*l.* in 1878, 7,669,314*l.* in 1877, and 5,651,357*l.* in 1876.

The lessons of this year showed that fluctuations of traffic must attend upon those of trade, but that the people were assuredly learning the value of railways. And notwithstanding the diminution of receipts from some sources, the aggregate receipts for the second time covered the amount of the Government advances.

1879.—The length of the whole railway system open for traffic at the end of 1879 was 8,611 miles, of which 395 miles had been opened during the year, the net revenue for 1879 amounting to 5,372,596*l.*

The net revenue derived from all railways in India during the year amounted to 5,372,596*l.* That from the

Guaranteed lines 5,062,188*l.* compared with 5,002,028*l.* of the previous year. The guaranteed interest paid by the Government was covered, leaving a balance in favour of Revenue of 313,955*l.* The net receipts of the State lines amounted to 310,408*l.* compared with 200,374*l.* of the year 1878. The gross receipts of the Guaranteed lines were 9,765,284*l.*, and the expenses were 4,703,096*l.* On the State lines the gross receipts were 1,465,824*l.*, and the expenses 11,555,416*l.*, shewing an average proportion of net receipts to expenditure on the Guaranteed lines of 51 and on the State lines of 22 per cent.

The capital expended up to the end of the official year was 123,124,514*l.* Of this 97,327,851*l.* had been expended on Guaranteed lines, 24,403,797*l.* on State lines, and 1,392,366*l.* on lines in Native States. The capital expenditure during 14 months in the case of the State Railways, 9 months in that of the East Indian Railway, and 12 months in that of the other guaranteed lines was 5,388,772*l.*, being 883,185*l.* on Guaranteed and 4,505,587*l.* on State lines.

The capital representing the guaranteed undertakings is now made up of 58,353,477*l.* of guaranteed stock, 4,751,450*l.* of debentures, 3,922,458*l.* of debenture stock, and 52,203*l.* of money not bearing interest. The East Indian Railway Company's capital was converted into an annuity of 1,473,750*l.* for 73 years; 230,217*l.* of which was exchanged for 5,115,938*l.* 15*s.* Four per cent. Government Sterling Stock and Rs. 1,06,750*l.* Four per cent. Rupee Stock. The stock and debentures above-mentioned were held, on the 31st December last, by 63,290 persons, of whom 59,084 stockholders were registered in England and 301 in India; the number of debenture holders was 3,905.

The number of passengers increased from 38,489,586 in the year 1878 to 43,144,468 in 1879. The proportion per cent. of first-class was ·519, of second 2·049, and of the lowest classes 97.432. The aggregate quantity of goods carried on all the lines amounted to 7,876,766 tons, as compared with 7,296,335 of the previous year. The amount received for the conveyance of the same was 7,248,752 as compared with 6,734,059*l.* in 1878. The expenses of working and maintenance during the year amounted to 5,774,510*l.*, compared with 5,101,335*l.* of the previous year. The cost of maintenance was 1,463,550*l.*, and of working 4,310,960*l.* The rolling stock employed in working the railways consisted of 1,850 locomotives, 4,294 passenger carriages, and 34,856 trucks. The total train mileage during the year was 28,915,144, compared with 26,570,395 of 1878. The passenger train mileage was 5,392,544, the goods 13,546,878, the minerals 357,561, and the mixed goods and passengers 8,964,032.

The goods shipped to India from this country for the use of the railways amounted during the year to 207,743 tons, of the value of 1,578,404*l.*, the freight and insurance of which was 315,181*l.* Besides this 143,279 tons of coal, 1,938 chaldrons of coke, and 8,393 tons of patent fuel were sent out. The total quantity of coal consumed on the railways was 512,858 tons, of which 362,762 tons were obtained from collieries in India. The cost of all this coal was 662,589*l.*, that from Indian sources varying at the point of delivery from 7*s.* 4*d.* on the East Indian, and 16*s.* 1*d.* on the Eastern Bengal (these lines being near the Bengal coal fields) to 41*s.* on the Rajputana, and 60s. per ton on the Indus Valley lines, that from England being 30*s.* 10*d.* per ton on the Great Indian Peninsula, 34*s.* 8*d.* on the Bombay, Baroda, and Central India, 32*s.* 7*d.* on the South Indian, and 36*s.* 9*d.* on the Madras lines.

1880.—During the year a greater extent of railway was opened for traffic than in any year since the commencement of operations. No less than 1,104 miles were added before the close of the official year. The sum expended was 6,374,353*l.*, the average cost per mile, taking broad and narrow guage lines together, was 13,844*l.* In 1870 the average cost was 16,445*l.* The total net revenue was 5,907,422*l.*; the gross receipts having been 12,099,593*l.*, and the expenses 6,192,171*l.* Altogether, the advances by Government for Guaranteed interest were covered by the receipts.

The expenses of working and maintenance amounted to 6,192,171*l.*, compared with 5,858,512*l.* of the previous year. The percentage of expenditure to gross receipts was 51·13, compared with 52·16 of the year 1879. The Guaranteed lines were worked at an average of 46·60 per cent., the State lines of 72·02 of gross receipts. The East Indian was as low as 33·04, and the Bombay and Baroda and Eastern Bengal were 42·57 and 42·85 respectively. The aggregate quantity of goods carried on all the lines amounted to 9,319,421 tons compared with 7,876,766 of the previous year. The amount received for the conveyance of the same was 7,671,709*l.* compared with 7,274,403*l.* The number of passengers increased from 43,144,608 in 1879 to 48,066,060. The average number per mile was 5,490, compared with 5,140, and the amount paid by passengers was 3,802,388*l.*, compared with 3,413,910*l.* The shipments of railway material from this country to India during the year amounted to 275,627 tons, of the value of 2,296,563*l.*, the freight for which was 422,463*l.* Besides the 145,041 tons of coal, 594 of coke and 8,845 of patent fuel were sent out. The coal consumed on the line amounted to 173,340 tons of English or Australian coal, 330,875 tons of Indian coal, 7,077 tons of coke, 8,383 tons patent fuel, and 183,634 tons of wood.

1881.—We have now reached the last report issued, at the close of whose year the total extent of railways open for traffic in India was 9,875¾ miles, a length of 726¾ miles having been added during the year.

The whole capital outlay on the railways amounted to about 134,200,581*l.*, of which 32,293,415*l.* had been laid out on State and Provincial lines, 2,590,608*l.* on lines in Native States, 67,329,179*l.* on Guaranteed lines, and 31,987,379*l.* on the East Indian Railway. The average cost per mile of

the 5 ft. 6in. guage lines has been about 16,000*l.*, of metre guage lines about 7,000*l.*

The net revenue, after deducting all expenses for maintaining and working them, amounted to 6,952,714*l.*, compared with 6,147,043*l.* in the previous year. The charge during the year for interest on the capital expended amounted to 3,272,651*l.* in the case of the Guaranteed lines, and taking the rate of 4 per cent., 1,395,360*l.* for State Railways. The surplus profits earned by the Guaranteed lines and East Indian were 652,195*l.* and 1,031,933*l.* respectively. Of this amount 326,097*l.* was paid to the Guaranteed Companies, and 206,386*l.* to the East Indian Railway Company, as their shares of surplus profits, the Government retaining 326,097*l.* from the former, 825,547*l.* from the East Indian profits.

The gross receipts in 1881 amounted to 13,725,953*l.* compared with 12,457,469*l.* of the previous year, and the expenses 6,773,239*l.*compared with 6,310,426*l.* The East Indian Railway earned 4,541,147*l.* at an expenditure of 1,446,316*l.* gross receipts from the Guaranteed lines amounted to 6,718,492*l.*, and the expenditure to 3,607,668*l.*; from the State lines 2,466,314*l.*, the expenditure being 1,719,255*l.*

The total net earnings on all the lines yielded a return of nearly 5*l.* 3*s.* per cent. per annum compared with 4*l.* 15*s.* in 1880. The East Indian and the Guaranteed line, together produced 6*l.* 4*s.* per cent. The Guaranteed lines separated from the East Indian, yielded 5*l.* per cent., and the State lines nearly 2*l.* 3*s.* The East Indian alone produced nearly 9*l.* 14s. per cent. The Great Indian Peninsula earned 6·28*l.* per cent., the Eastern Bengal 9·46*l.* per cent., the Bombay and Baroda 6·55*l.* per cent. Of the State lines, the Rangoon and Irawadi earned 5·04*l.* per cent., the Rajputana-Malwa 3.94*l.* per cent., and the Northern Bengal 3.63*l.* per cent.

The number of passengers increased from 48,066,060 in 1880 to 52,271,133 in 1881. The proportion per cent. of first class was ·39, of second, 1·74, and of the lower classes, 97·74. The receipts from passengers were 4,089,842*l.*, compared with 3,899,701*l.* of 1880. The aggregate quantities of goods carried by the railways amounted to 13,211,082 tons, compared with 10,453,137 of the previous year. The amount received for the conveyance of the same was 9,151,168*l.*, compared with 7,918,356*l.* in 1880. The great increase was in grain and cotton.

The rolling stock employed last year in working the railways consisted of 2113 locomotives, 4,823 passenger carriages, and 41,089 trucks. The total train mileage was 34,403,205, compared with 30,172,323 of 1880. The fuel consumed amounted to 559,660 tons of coal, 154,318 of wood, 7,935 of coke, and 9,360 of patent fuel. Of this 173,951 tons of coal was supplied from England.

The reader is now in possession of authentic returns for the past seven years, exhibiting the annual progress made by the Indian Railways in their every phase during that period. Those of earlier date are before us, and will be presented as a summary in a future issue, but for all practical purposes those now given will be found sufficient. Before commenting on these, however, it is necessary to explain the initial difficulty encountered by the authorities, and to describe the relative positions of the lines themselves. The difficulty lies in the fact that hitherto private enterprise has declined to have anything to do with them except on the safest of terms—a Government guarantee. Certain lines are now being promoted by private companies, but the report for the current year is the first that contains so hopeful an indication. It was in 1869 that the Government determined to supplement the system of trunk lines undertaken by Joint Stock Companies on the Guarantee principle, by a system of *State* railways to be constructed under the direct supervision of Government. The length of these completed in 1881 was 2,687 miles. Much of this consists of branches and feeders to trunk lines. Hitherto the terms "Guaranteed" and "State" sufficiently described the railways to which they were respectively applied, although it would appear that both have been constructed by means of capital invested under a guaranteed interest of from four to five per cent. But there is this essential difference between them,—a Guaranteed line signifies one projected with a reasonable hope that it will soon become remunerative, while a State line, constructed in many cases more for military than commercial purposes, is not expected, at all events at the outset, to yield as large a revenue as the other. But the developing powers of railways are forcibly shown even by these State lines. In their early youth the authorities are not surprised if the yield from them reaches only 2 per cent., but when they have been opened some time it is found that they create a traffic for themselves and some have earned as high a return as 6½ per cent.

There are certain sub-divisions of State lines known respectively as "Productive," "Protective" and "Provincial," to indicate the financial footing on which they are undertaken and worked. A *Productive* work in the technical language of Indian accounts, is paid for out of borrowed money, and, whether a railway or a canal, is one which is calculated to yield a fair return on the capital outlay upon it within a certain time, that is, such a clear annual revenue as will cover the interest on the capital expended. In the case of railways, it has been ruled that, to justify a line being classed as Productive, there must be good prospect of interest at the rate of 4 per cent. per annum being earned within five years from the date of the line being open for traffic, on the whole capital outlay, including arrears of simple interest incurred up to that date, and the capitalized value of the land revenue and leave allowances and pensions to the officers and servants. In the case of irrigation works, they are classed as productive only if they can fairly be estimated to prove remunerative to the

same extent within ten years of their completion. It has been decided that, for the present, the amount to be annually borrowed for expenditure on Productive Public Works shall be limited to 2,500,000*l.*, or 250 lacs of rupees, and that this shall be distributed in certain proportions, to be fixed each year, amongst railways, canals, and miscellaneous works.

Works which would, from their general character, be productive of revenue, but would not comply with the stringent conditions laid down to admit of their being technically classed as Productive, have been termed *Protective*, on account of their commonly serving as protection against famine, by facilitating the import of food in times of scarcity, or adding to the security against drought. A railway or a canal constructed primarily for these purposes will it is true, in almost every case, sooner or later, yield a surplus revenue, and in one sense be more or less productive. It would be difficult in India to find a district where a railway would not be the means of developing trade and stimulating agricultural produce, and thus obtain a traffic which would become remunerative, while it would also bring into it, during a period of scarcity, food from places where it is plentiful. But this does not suffice to admit of the grant ot borrowed funds for the construction of such works, and a certain sum has been appropriated from the yearly revenues to be applied to those undertakings which will be the means of relieving the country from famine. There are, unhappily, areas on the continent of India periodically liable to such calamities. The districts have been recently pointed out, and the comparative intensity of the visitations shown, in the report of the Famine Commission appointed by Lord Salisbury in 1878. After a searching investigation of the whole subject, in the course of which a mass of valuable facts was collected, and complete information on the physical and meteorological characteristics of the various parts of the country obtained, the Commissioners, who were Lieutenant-General R. Strachey, R.E., C.S.I. (Chairman), Mr. James Caird, C.B., Mr. H. C. Cunningham, Mr. H. E. Sullivan, and Mr. J. B. Peile, reported their conclusions as to the best course to adopt for the future protection of those districts that in past years have been subject to famines, and which will always, from the causes which have hitherto prevailed, be liable to seasons of drought, followed by severe scarcity or famine. The conclusions include recommendations for the extension of railways and canals or other irrigation works. The outlay, of course, would be large, before all that is necessary can be provided, and the means are limited. It has been determined that a sum of 750,000*l.* should be appropriated annually for these purposes out of the 1,500,000*l.* which it is resolved to set apart from the revenue of each year as a "Famine Insurance Fund." If this limit is preserved, a long time must elapse before a complete scheme of protection can be finished; but it may be hoped that it will be possible, as the revenues of the country improve, to spend more on productive works, which would also help to secure the country against the disastrous effects of future drought and famine.

The term *Provincial*, applied to works of a productive character, means that they have been undertaken on the financial responsibility of the Local Government of a province, under a suitable arrangement with the Supreme Government. The capital is either provided by the Government of India or from provincial sources, or it is borrowed locally, the revenue of the province being held responsible for all interest that may be due on capital advanced by the Imperial Governments. Arrangements of this description have been entered into with several of the Provincial Governments, particularly those of Bengal and the North-West Provinces, and 32,410*l.* of the capital for the Muttra-Huthras line; 45,020*l.* of that for the Cawnpore Furrakabad line, 50,000*l.* of the Dildarnagar-Ghazipur, and 43,270*l.* of the Nagpur-Raipur lines have been raised by means of debenture loans from local residents, who receive interest at 4 or 4½ per cent., and share in surplus profits.

It is, however perfectly clear that the provision made under these different heads is altogether inadequate to meet the existing and constantly increasing wants of India, and Major Baring, in his financial statement at Calcutta, in March, 1881, gave a very clear exposition of the state of affairs. In 1879, he explained, a Committee of the House of Commons recorded its opinion that the expenditure on railways and irrigation works in India, though not always remunerative, and sometimes wasted on profitless schemes, had, on the whole, been beneficial to India, and the policy of borrowing for productive public works might be continued under certain restrictions, one of these being that not more than 2½ millions should be borrowed in any one year. Major Baring thought this restriction justified, and some of his reasons for the opinion are both significant and interesting. One is the limited amount of capital available in India; another, that there is little or no publicity, and less extraneous engineering talent to criticise the projects emanating from the Public Works Department; a third, the difficulties encountered by a great central department in exercising an effective control over the expenditure of vast sums of money. Here is indeed a happy hunting ground for the adventurous. The budding financier must sigh for opportunities of making "available" the countless billions of lacs which undoubtedly exist in the country; and who cannot imagine the yearnings of the ambitious engineer to criticise the performances of his official brother, in a land where there is "little or no publicity," and where great central departments "cannot exercise an effective control over the expenditure of vast sums of money?"

(*To be continued.*)

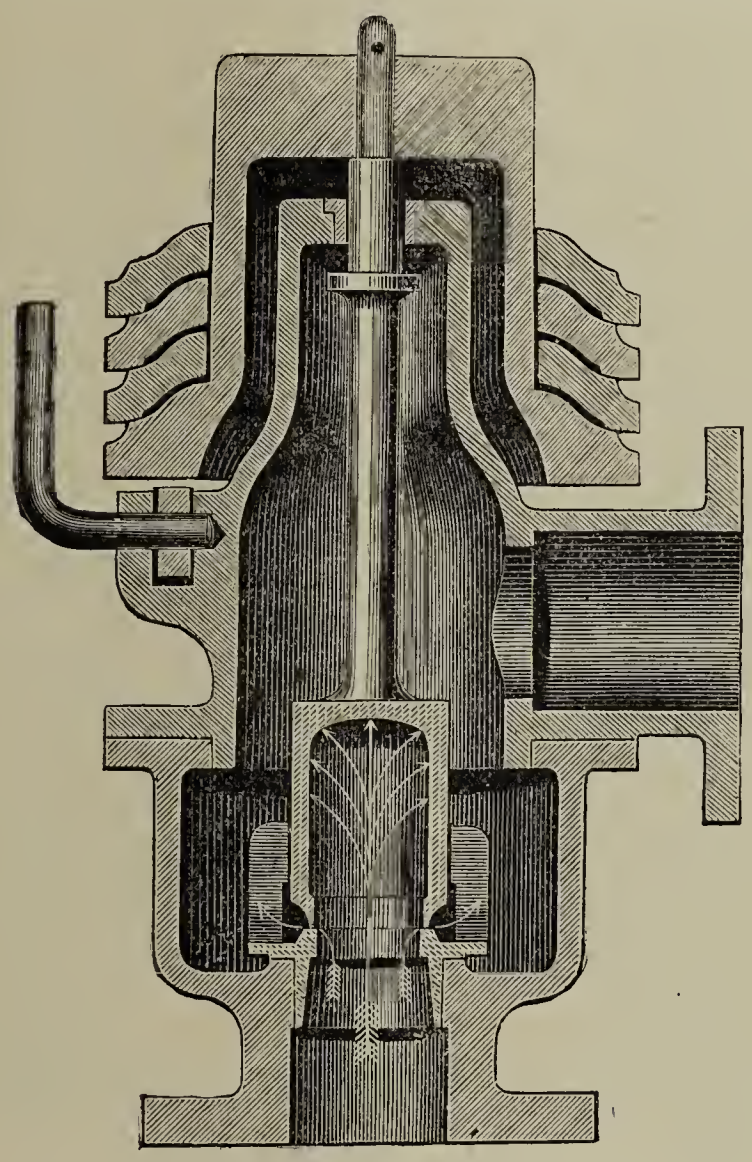
TURNBULL'S SAFETY VALVE.

IF all the varieties of safety valve mechanism were efficient, we might receive fewer records of disastrous boiler explosions; but like other apparatus designed to avert danger—the safety valve is not what its name implies. When not absolutely efficient and reliable it becomes a "dangerous" valve, for it leads those who have charge of the boiler, which it is supposed to protect, into a most perilous sense of security. It has frequently happened during experiments by officers of the Board of Trade and others that, the safety valves attached to boilers, and believed to be effective, have proved utterly useless as precautions against dangerous pressure. In many instances the valve area is insufficient.

Messrs. Alexander Turnbull & Co., of St. Mungo Works, Glasgow, are the patentees and manufacturers of an equilibrium safety valve, which appears to have been specially designed to meet all possible contingencies, and to avoid those known causes of failure in similar life-saving appliances.

We extract the following description of this valve from a contemporary:—

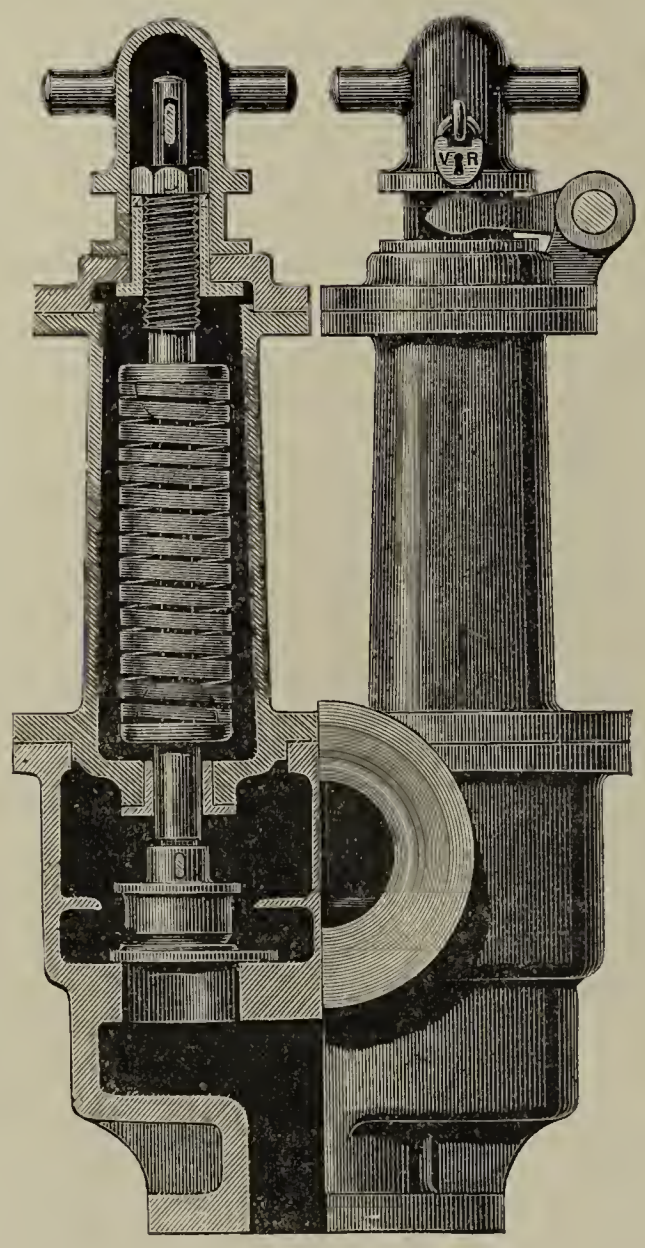
"It is used chiefly for stationary boilers, and they are such that, when the boiler pressure is equal to the valve load, the valve is practically in a state of equilibrium, so that increase of pressure is prevented. They give a gradual, steady, and full opening; they also close again practically at the opening pressure. The valve load required is only from one-tenth to one twentieth of that required by ordinary valves. The valve is guided externally by six feathers which project up from the valve seat, also by the spindle passing loosely through a brass bush in the central boss of the escape pipe. The valve is loaded to 20 lb. per square inch by the cylindrical weight, the central boss of which rests upon the top end of the spindle, and each of the ring weights, as shown, applies an additional load equal to 10 lb. per square inch. The valve is eased or blown off, when necessary, by the handle H, and a small eccentric, lifting up the weights, and in such a manner that the valve is partially turned round, and in re-closing comes down on a fresh bearing surface. Fig. 2 is a similar valve to that shown in Fig. 1, except that a side branch pipe is provided in order to conduct the waste steam in any desired direction.

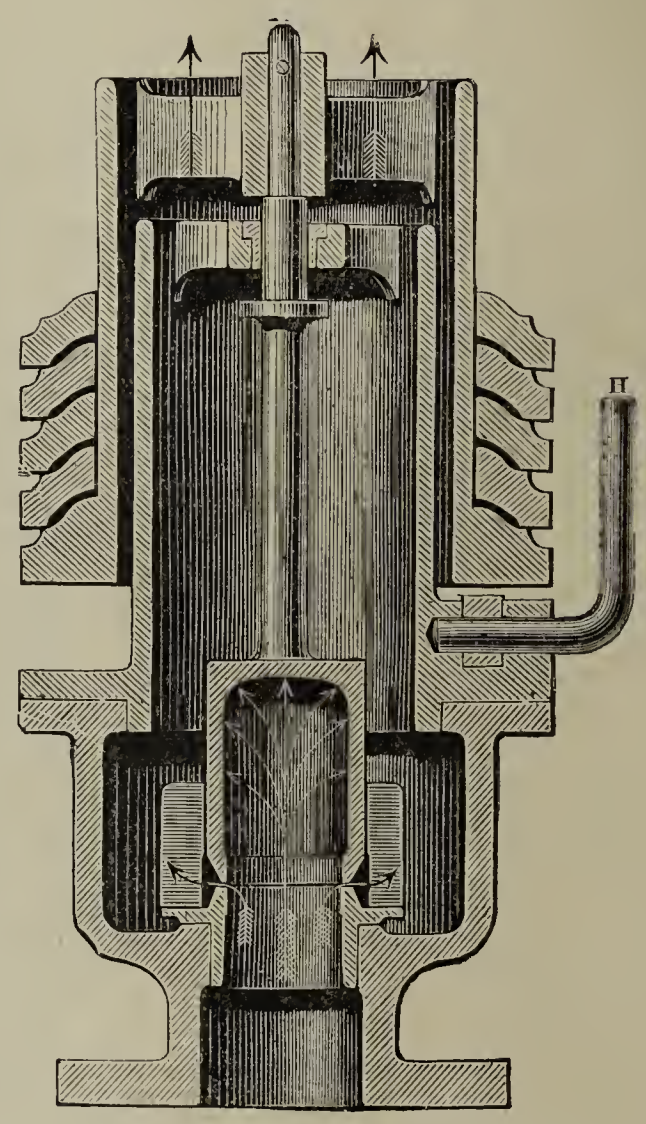


This form of valve is frequently provided with a cover, so as to encase the weights, the valve thus being made to lock up, tampering being thereby rendered impossible.

"Fig. 3 shows a pair of spring-load lock-up valves in one chest) for marine purposes, as made to pass Board of Trade and Lloyd's registry. In these valves, as in the others, there is an absence of internal guide ribs, &c. They are guided exclusively by the spindle and by only two bearings, so that the friction in working is reduced to a minimum, The loading of the valve is effected by the compressing of the spring by the screw at the top of the valve. After the valves are set to the working pressure, a distance ring is inserted under the head of the compressing screw, so as to prevent any further compressing of the spring.

"We select one experiment of the many available, as showing the great efficiency of the 'Turnbull' over the ordinary valves. This experiment was made at the Crown Ironworks, Glasgow, upon a new double-flued boiler with 18 Galloway tubes, and having 31 square feet of fire-grate. The boiler was fitted with two weighted leversafety valves, each 5 inches in diameter. The valve area, therefor was more than $2\frac{1}{2}$ times the Board of Trade rule, being 39·6 square inches for 31 square feet of fire-grate. The valves began to lift at 46 lb., and to blow at 47 lb. The pressure increased in the boiler to 55 lb. before all the steam generated could escape, being an excess of 9 lb. Upon this boiler was fitted one of the Turnbull safety valves, $1\frac{1}{2}$ inch in diameter. This valve began to lift at 48 lb., and it was found that though the fires were urged to their utmost, the pressure in the boiler could not be got to exceed $50\frac{1}{4}$ lb. The pressure oscillated between $50\frac{1}{4}$ and $49\frac{1}{4}$, showing that this small valve was more than a match for the boiler, and that although it was only 1-23rd part of the area of the two 5-inch valves, it was four times more efficient in preventing increase of pressure. This valve was one of the first made. They can now be seen giving an opening of one-fourth of the diameter with an increase of 1 lb., and will close promptly at almost the identical pressure at which they open. From what we have stated, it will be seen that the Turnbull valve meets both theoretically and practically the requirements of a perfect safety valve, and as such we commend it to the notice of our readers. Its value is established in practice, where it has proved very successful, as shown by numerous testimonials from firms of high repute which are now before us."





OFFICIAL REPORTS ON RECENT ACCIDENTS.

Major Marindin has reported the result of his inquiry into the causes of a collision which occurred on the 22nd September last, at Liverpool Central station, on the Cheshire Lines Railway. The driver of the Midland express train is solely to blame for this collision, first for having disobeyed the rule which lays down that trains running into terminal stations, of which the Central station, Liverpool, is one, are to run at such a speed that they may be stopped by means of the hand-brakes alone, and secondly for not having made use of all the brake power at his command until he was dangerously near to the end of the platform, for he admits that he was running at 15 miles an hour when only 311 yards from the buffer stops, and that he did not attempt to apply the steam brake on his engine and tender until he was within 150 yards of the buffer stops. It would, however, appear from the evidence that the brakes upon this train did not act as they should have done when they were last applied, for, if they had, the train brake, which was undoubtedly applied when leaving the tunnel mouth, 311 yards from the buffer stops, or very soon after, ought certainly to have so reduced the speed that the driver might without difficulty have stopped his train at the proper place, by the application of the steam brake when he had still 140 yards to run. It is impossible to say, with certainty, whether this was due to any fault in the hanging parts of the brake, such as the blocks being too far off the wheels, or to the driver not having taken steps to maintain the necessary power; but, as the brakes seem to have acted well throughout the journey, and were found to be in good order after the collision, I believe that the failure to act properly was due to the latter cause. The statement of the driver that his train brake and steam brake were both full on from a point 30 or 40 yards inside the distant-signal to a point 100 yards outside the home-signal, that is, for a distance of 560 yards, is clearly incorrect, for, if this had been the case, the train must, if the brakes were worth anything, have been stopped altogether in the tunnel; but, taking the statements of the fireman and guards as being more accurate, it is clear that the train brake was on to some extent for a considerable distance and time before the driver released it upon sighting the home-signal. The rear guard says that it was released when near the home-signal, but did not come fully off, and that, when applied again, it did not seem to act properly; while the front guard says that it came fully off the front brake-van, and that he does not think the blocks came on again upon the front brake-van at all. It is probable, therefore, that the brake was applied slightly only after passing the distant-signal, and remained slightly on until the home-signal was sighted, the power gradually diminishing on account of the leak-hole in the piston-head; that, when the driver released the brake near the home-signal he did not make sufficient use of his large ejector, and consequently did not take the brake fully off, and did not create a sufficient vacuum to render the brake effective when he resorted to it after leaving the tunnel. It is true that the driver states that he saw that he had blown the vacuum to 15in. on the gauge, but he was then in the dark and may easily have made a mistake, while it is rather remarkable that the number of inches which he has stated, viz., 15, is the minimum number at which he is allowed by the rules to run. I think that the unsatisfactory manner in which the train brake behaved upon this occasion strongly supports the conclusion which was arrived at by Colonel Rich, when reporting upon the somewhat similar accident which occurred on the 25th April, 1882, at Portskewet on the Great Western Railway, viz., that the efficiency of this class of brake is materially interfered with by the leakage hole in the piston-head. It is alleged that whenever trains are observed to be running into this station at a dangerous speed the drivers are reported and punished, but I do not consider that the station-master's definition of what is a dangerous speed, viz., something over 15 miles an hour when only 311 yards from the buffer stops, is by any means to be accepted as correct; and I have no hesitation in saying that unless this rate of speed is very much reduced, there is grave risk of further accidents at this station. It is quite certain that a train running at 15 miles an hour when leaving the tunnel mouth could not be stopped at the proper place by means of the hand-brakes alone, and I believe that the only safe regulation would be that trains entering this and other terminal stations are to be brought to a stand, or any rate to a walking pace, at the home-signals, letting the driver then apply steam, if necessary, to draw the train up to the platform.

Colonel Rich has reported the result of his inquiry into the circumstances which attended the collision that occurred on the 9th October last, near Proof House junction Birmingham on the London and North-Western Railway. This collision, which occurred during a dense fog, appears to have been caused by the mistake of the signalman at New Street station, Birmingham, who seems altogether to have forgotten to telegraph the London and North-Western train to the Proof House junction signalman, who was not aware of its approach, and consequently the train was stopped by the Proof House junction signals, which were kept at danger. The train came to a stand just outside the junction home-signal. The man on duty in the Proof House cabin did not hear the driver of

the London and North-Western train whistle, owing to the noise in the goods yard adjacent, or for some other reason. When the Midland train was telegraphed to him from New Street, Birmingham, he appears first to have endeavoured to call the New Street signalman's attention to the fact, that he had not received the London and North-Western train, which he knew should precede the Midland train. He failed to make the signalman at New Street understand what he meant, and when he received the "Be ready" a second time for the Midland train from New Street he accepted it, and took off his signals for that train. When the London and North-Western driver, who was waiting for signals, observed the signal for the Midland train taken off, he sent his fireman to the Proof House cabin, to inform the man on duty, that the London and North-Western train was waiting, but immediately after the fireman reached the cabin the collision occurred. In consequence of the proper signals having been lowered for the Midland train it ran on until it struck the London and North-Western train, which was standing just outside the junction home-signal. The mistake of the signalman at New Street might probably have been rectified if the signalman at Proof House junction had used his speaking instrument, as he should have done, to communicate with New Street, instead of using the indicator instrument. Both these signalmen bear excellent characters, and appear to have been doing their best to work the traffic safely during a dense fog. The fogman, who had reached his post at the Proof House distant-signal before the Midland train arrived, took up the fog signals he had placed on the rails to protect the London and North-Western train, when he saw the signal lowered for the Midland train, as he was under the impression that the London and North-Western train had gone past Proof House junction before the signal was lowered. There had been plenty of time for it to do so if the signalman in Proof House junction had known of its arrival.

Colonel Yolland has reported the result of his inquiry into the circumstances which attended a fire in a Pullman car in the Midland down night Scotch express train on the early morning of the 29th October last, close to Hunslet station near Leeds, on the Midland Railway. From the statements it appears that the Midland down Scotch night express train left Normanton all right for Skipton at its appointed time, 1.37 a.m., on Sunday the 29th October, or within one minute of that time. The communication cord was tested before it left the station. Hunslet station is nine miles from Normanton, and it is said that there was nothing unusual with the train when it passed Rothwell Haigh signal-box, 6¾ miles from Normanton at 2.9 a.m., travelling at its usual rate. The signalman there was looking out, and he observed that the Hunslet south junction down distant-signal stood at "danger" as the train approached it, but the danger signal was taken off shortly before the train reached it, and almost immediately the signalman observed an unusual light in connection with the train, and he thought the driver had opened the fire-hole door of the engine, and that the light was a reflection from the engine fire. The driver of the train (Carlisle) states that as he approached the Hunslet south junction down distant-signal he found it on at "danger" against him, and when he was near to the Rothwell Haigh *up* distant-signal the "danger" signal was taken off, and when he was a short distance outside this signal the whistle to which the communication cord of the train was attached was sounded; that he looked back on the six-foot side of the train, his own side of the engine, and observed that there was an unusual light on the top of a car. He then stepped on to the near side of the engine and saw a light, but could not tell whether it was a light from a car, or what it was. He then went back to the six-foot side of the foot plate, and again looked alongside the train, and found the light still there; that at this time his train was within the down distant-signal, and he shut off steam and applied the Westinghouse continuous brake, and the train was brought to a stand a short distance on the Leeds side of the Hunslet south junction signal-box; that he was running at the time at from 45 to 50 miles an hour, and he believes they stopped at about 2.11 a.m. The signalman in the south junction signal-box (Busby) stated that the train passed his box at 2.10 a.m, and that the rear vehicle stopped about 100 yards north of his box, which would make it appear that the rear end of the leading half of the train, the car "Enterprise," stopped at about 177 yards north of the signal-box. The driver's statment as to the stopping of the train is confirmed by his fireman. The guard riding in the leading van was not aware that anything was wrong until the train was in the act of stopping, as he did not hear the communication cord whistle on the engine sounded, and the guard in the van at the rear of the train was also not aware that the whistle attached to the communication cord had been sounded, or that anything was wrong with the train, but on passing the over-bridge near to the Hunslet south junction signal-box he perceived smoke, and noticed that the train was being brought to a stand. The pulling up was a sharp one. He says that he was aware that the brakes had been applied to the van in which he was riding: he had the power of putting on the continuous brakes: he did not hear any alarm whistle before the brakes were put on. In the meantime the conductor (Baillie) travelling in the Pullman car "Excelsior" for Glasgow, placed immediately behind the Pullman car "Enterprise" for Edinburgh, states that they left Normanton station at about the right time, and he rode in No. 1 berth on the off or right side at the leading end of the sleeping saloon, as the train was running, and there was nothing between him and the Edinburgh car "Enterprise" except the lavatory in his own car; that after leaving Normanton some minutes, he could not state the exact time, he noticed a glare

on the head-board of No. 8 berth in his own car, on the board which divides the berths, and at first thought that it was the reflection from some light upon or near the railway; but on looking out of the window of No. 2 berth (on the opposite side of the car) where the blind was up, he observed that the reflection continued, and he got up and looked through the front door and saw flames in the Edinburgh car, at the rear of the car; no window in the door was then broken; that he then opened the door at the leading end of his car, and went on to the platform between the Glasgow and Edinburgh cars, and stood on the platform of the Glasgow car; that he took hold of the communication cord, and pulled it; he pulled in the slack of the communication cord, did not fasten it, but let it go; that he heard no whistle, and at this time his cap was blown off his head; the south door of the "Enterprise" car was still shut, and directly after he noticed the window in the door at the rear end of the car "Enterprise" broken, and smoke and flames proceeding therefrom. Coming to the outside of the car at the south end, he had not at that time seen Donaldson (the conductor of the car "Enterprise"). This had a very serious aspect, and he at once decided to pass through his own car and arouse the passengers, and this he did without telling them the reason why, as he wished to avoid creating any serious alarm, as he had lady passengers in the car. That he passed out of the car at the rear end, and took hold of the communication cord and pulled it again, and directly afterwards found that the train was being stopped, and it shortly afterwards came to a stand. That he left his car at the rear end, and ran forward on the ballast; flames were at this time issuing from the roof at the rear half of the Edinburgh car, and he called out for some one to divide the train between the cars in order that the Glasgow car might be saved. This was quickly done by some one who was shortly on the spot; and in a very short space of time a supply of water, perhaps a dozen buckets, was quickly brought forward, and the car was moved a short distance ahead, away from the Glasgow car, and water was thrown upon and into the car, but not before the front part of the train had been moved forward. This man's cap was picked up 1,319 yards south of the spot where the rear end of the "Enterprise" car stood when the train was stopped, so that it had run that distance after the communication cord was pulled by conductor Baillie, before the train was stopped. Conductor Donaldson in charge of the Pullman car "Enterprise" for Edinburgh, states that they left Normanton at 1.57 a.m., the proper time, and he went into the main portion or leading end of the car, and found that Mr. Cranston, who had entered the car at Sheffield, had gone to bed in the first lower berth, No. 8, on the near side of the car, the nearest to the private rooms. He had a reading lamp burning, fixed to the narrow window curtain (this was, strictly speaking, a window blind); that he called his attention to the lamp being burning, and he said it would be all right, he always had a light to read by before going to sleep, but he would blow it out before going to sleep. He was reading a paper like "Truth." That he wished him to be careful, and he promised that there need be no fear, as he always had a light before going to sleep. That he then left him,and returned to the rear, portion of the car; to ease his head he took off his uniform cap, and placed it in one of the private rooms; he then stood near to the stove-room to warm himself, as he felt somewhat cold, and whilst standing in this position travelling backwards a heavy atmosphere appeared to come over him; that he turned round, and at this time a noise was made of flames escaping with a sort of puffing noise. The door at the rear of the car was shut, and the glass in it was sound. He then turned to go to the passengers, and screamed out that the car was on fire, and he saw Mr. Cranston in bed at that time. He then returned to the south end of the car, and then went towards the Glasgow car to obtain assistance from his mate (Baillie), but on reaching the rear end of his car the flames were all over the door, and escaping through the window of the door, which was enveloped in flames, and he could not open it. The door was not locked, but the handle was hot. He then returned through the main portion of the car to the platform at the front or north end. Mr. Cranston followed him to the north end of the car on to the platform; he had met him at the north end of the gangway. He laid hold of the communication cord, and pulled it down, but did not hear any noise in response; did not hear any whistle. The cord at this time was very tight, and thinking he could not attract the attention of the driver, and believing that if he turned the taps of the Westinghouse brake, it would have the effect of applying the brakes in the train, he knelt down upon the platform and turned two taps, one on the bogie carriage in front, and one on the car upon which he was travelling, and in a very short time the speed of the train was reduced, and it was quickly brought to a stand. He left the car at the leading end on the near side. I have now recited what had happened up to the time when the train was stopped according to the evidence of the Company's servants and the Pullman car conductors. 2. When the train had nearly stopped, the engine driver sent his fireman back to see what was amiss, and he returned almost immediately, and said that a car was on fire inside. That at this time one of the men at the burning car had uncoupled the train between the two cars, and he received a hand signal to draw ahead, and he drew the front portion of the train, including the burning car, a short distance ahead, about two carriage lengths, and the engine driver went to the burning car, taking two buckets of water with him. He found several of the Company's servants (from the Hunslet sidings) engaged with buckets throwing water on the car, one of the men standing on the platform of the car at the rear end for the purpose of receiving the water from the other men, and throwing it upwards inside the car towards the top. The rear end

appeared to be most on fire, not towards the front end of the car. He says it was found that the water thrown inside the car with buckets was not having the effect of subduing the fire, and it was decided to draw the burning car to the water crane, near the Hunslet passenger station. The water crane is only 105 yards south of the Hunslet station signal-box, so that the burning car had to be moved 876 yards ahead from where it had stopped to be opposite to the water crane. I must not omit to mention that three out of the four passengers who who were riding in the sleeping saloon got out of the car before the leading half of the train was moved forward to the water crane. Two of these passengers and the conductor Donaldson got out of the car through the door at the leading end, and the third passenger forced out the window of the berth No. 5, in in which he had been sleeping, and got out of the car through this window. The fourth passenger, Dr. Arthur, was awake, and spoke at this time, but, according to the evidence, he had been under the influence of drink or some stupefying drug. But it seems certain that there was nothing to have prevented him from escaping from the car at this time if he had been conscious of what was going on. The conductor Donaldson states that he was placed in No. 3 berth at Leicester, the second from the front on the off side; but it was stated that he was ultimately found dead in No. 7, the fourth berth from the front on the off side, next to the berth in which the window was forced open, and a passenger, Mr. Main, escaped through it. At the time when the front half of the train, including the burning car "Enterprise," was moved ahead to the water crane, there was no fire of any importance in the sleeping saloon; and although it is quite true that the front part of the car is that which was ultimately most damaged, this actually occurred after the first half of the train was being drawn forward to the water crane. It was found that when the burning car reached the water crane, the top of the car was too high, about 13 feet above the level of the rails, to allow the hose from it being turned on to the top of the burning car, which was then separated from the bogie carriage in front; and then the car was pushed back a short distance, and placed under a hose from Messrs. Nicholson's chemical works, when the fire was ultimately put out. Efforts appear to have been made to enter the burning car to search for another passenger before it was drawn forward to the water crane, but it is stated that it was found impossible to do so, on account of the fire. A mistake appears to have been made in taking the front half of the train on to the water crane, and it seems possible that if the efforts had been continued to pour water into the car when it was first separated from the Glasgow car "Excelsior," these might have been successful, and Dr. Arthur's life might have been saved. No blame is attributable to the Company's servants for what seems to me to have been merely an error of judgment on their parts, in moving the train nearly half a mile ahead. 3. There is no positive evidence to show in what manner the fire originated. The stove for heating the water that warms the car is said to have been all right when the train left Normanton. The fire in the stove had been made up between Bedford and Leicester, and the conductor says he thoroughly examined the stove at Leicester, and found it in perfect condition with the dampers well down, and everything fitted well and close, and that he twice looked at it before reaching and immediately after leaving Normanton. The car was illuminated by 10 lamps when the train left St. Pancras, but the conductor, after leaving Leicester, put out all the lamps, except one lamp burning in each of the vestibules at the two ends of the car, one in the second private room, and one in the main saloon, leaving only four burning. These lamps were all trimmed before the commencement of the journey, and no oil was carried for the trimming or replenishing of the lamps on the journey. One of the passengers from Sheffield, a Mr. Canston, had a lighted reading lamp in No. 8 berth to read with after he went to bed. It is a little doubtful whether he was in bed before he reached Normanton or not, but it appears certain that he was in bed with a lighted reading lamp suspended from the window blind, when the train left Normanton, and was reading. He said before the Coroner that he put out his light, and did not go to sleep. He gave the conductor Donaldson a cigar to smoke, and their statements as to what happened in the car when the fire was discovered cannot be reconciled. I have examined the stove, and made inquiries of the Pullman Palace Car Company as to the occurrence of any fires having taken place in any of their cars in this country, and I give in Appendix (B) the particulars of the only fire of which they have any knowledge. I can see no way of accounting for this fire having taken place other than by supposing that it was occasioned by this lighted reading lamp in No. 8 berth, either whilst burning and igniting some substance, or in the act of its being blown out, by some spark or sparks coming in contact with some combustible material. The flame being fanned by the draught in the car might have caused it to burn upwards and backwards to the rear end of the car. The fire seems to have been first discovered by the conductor of the Glasgow car "Excelsior" (Baillie) placed next behind the Edinburgh car "Enterprise," and this fact obliges me to doubt the accuracy of the statement of conductor Donaldson as to his having been standing alongside of the stove warming himself. It seems to me that he must have been in one of the sitting-rooms, where he admits that he took off his cap to ease his head, otherwise he would have been seen by Baillie when he went to the front of the car and pulled the communication cord. I do not think he can have been aware of what was going on, otherwise he ought to have been the first to discover the fire. He had been smoking, and was thus breaking one

of the Company's few rules; and in the fright and alarm caused by the fire, probably lost his judgment as to waking up the passengers in the car, including among the number Dr. Arthur, as he was conscious of his state when he pulled off his boots and put him to bed in No. 3 berth. 4. I do not think the engine driver or fireman are to be blamed for not having at once put on the Westinghouse continuous brakes and stopped the train immediately they heard the alarm whistle sounded. The Company's rule respecting the cord communication corresponds, I am told, or nearly so, with the rules issued by the larger portion of the railway companies in the United Kingdom. It says:—"When the guard hears the bell rung, or the engine-driver hears the whistle on his engine, he must at once look carefully along each side of the train, and in case any oscillation be noticed, or a vehicle be on fire, or other occurrence of a serious character be observed, the train must be stopped as speedily as possible, and when stopped must be protected by signals, as prescribed in the Company's regulations. Should, however, the guard and engine-driver fail to observe anything that really necessitates an immediate stoppage of the train, the train must be stopped at the first station or junction where it can be properly protected by fixed signals." But this rule was framed under very different circumstances to those which exist at the present time as regards the making up of trains and the mode of working the traffic. Then, the working of the traffic under the absolute block system had not been very extensively adopted and carried out, even on the main lines of railway, and few companies had assented to the propriety of fitting all passenger trains with continuous brakes, and even now all railway companies do not admit that these brakes should be made automatic in action. It is urged on the part of the Midland Railway Company that this rule (see Appendix C.) was partly based on a recommendation of mine when reporting the terrible accident which occurred at Shipton-on-Cherwell, on the Great Western Railway on the 24th December, 1874; but in my report dated the 27th February, 1875, I pointed out that the train in question was not a properly equipped train, having an entirely insufficient amount of brake power fitted to it, and having no less than six vehicles behind the last brake van; that the cord communication (Harrison's) failed on that occasion to act, and that the drivers of the two engines at the front of the train at once reversed their engines without actually looking back and observing that the vehicle next the last tender was running partly off the rails, and they thus applied a heavy retarding force at the front of the train, and thus pushed that vehicle altogether off the rails, as there was no retarding force at the tail of the train to keep it properly stretched on the line. Now the circumstances in this case are entirely different. Here a well-appointed train with the Westinghouse continuous automatic brakes fitted throughout the length of the train, and running on a main line of railway worked on the absolute block system, suddenly has the alarm whistle sounded on the engine, to give notice that something was wrong. If that alarm whistle had been sounded by the communication cord being broken by the separation of the train into two parts, the automatic action of the brakes would at once have acted on the separated parts, have reduced their speed, and thus brought both parts to a stand, without, as far as I can see, the slightest risk to any individual in the train, passenger, or servant of the Company; but as no such stoppage did take place, the driver must have known that it was an alarm whistle sounded by some passenger or servant of the Company giving him notice that something was wrong in the train in order that it might be stopped. 5. By the 31 & 32 Vict. cap. 119 sec. 22 (1868) it was enacted, "That every company shall provide, and maintain in good working order, in every train worked by it which carries passengers, and travels more than twenty miles without stopping, such efficient means of communication between the passengers and the servants of the company in charge of the train as the Board of Trade may approve. If any company makes default in complying with this section, it shall be liable to a penalty not exceeding ten pounds for each case of default." A system of cord communication practically known as Harrison's cord communication, was submitted by a Committee of the General Managers of the principal railway companies, of which Mr. Allport, of the Midland railway, was chairman, and provisionally sanctioned by the Board of Trade for the railway companies who had applied on 27th February, 1869. This provisional sanction was finally withdrawn by the Board of Trade on and after the 1st August, 1873, and no subsequent sanction has since been given by the Board of Trade for any other cord communication, so that the system in use on the Midland down night Scotch express on the 28th and 29th October, was not approved by the Board of Trade as required by the above-mentioned Act, and the Company appears to be liable to the penalties named in the Act. On this occasion the cord acted properly, but I must point out that it could not have been pulled by either of the conductors of the Pullman cars without opening a window of the car or passing through a door out on to the platforms at the end of the cars, thus causing a draught through the car,—the thing of all others most calculated to encourage the burning of the car. It was not in fact such a means of communication as the Board of Trade could properly sanction. It is impossible to say positively whether conductor Donaldson turned the taps at the front end of the car "Enterprise" before the engine-driver put on the Westinghouse brakes or not. If before, that would have reduced the retarding force of the brakes by about one half. If the brakes were put on before the taps were turned, it must follow that the train must have run nearly 1,000 yards after conductor Baillie lost his cap, while in the act of pulling the communication cord, before the brakes were put on, inasmuch as a train fitted as this

train was, would have been pulled up by the Westinghouse brakes in 300 yards after they were applied. This time was occupied by the driver in obeying the rule which I have quoted, and which appears to me to be wholly unsuitable for all properly equipped passenger trains running on lines where the traffic is worked on the absolute block system. If the train had been stopped as soon as the alarm whistle was sounded, I think it highly probable that Dr. Arthur's life would have been saved. 6. In all cases of murder or outrages in trains, or of carriages taking fire, seconds of time saved are invaluable, and I trust no long time will elapse before this rule will be altogether changed. I also think that lighted reading lamps should not be permitted in sleeping berths occupied by passengers.

NOTES.

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Darlington Exhibition.—The Prize Medal credited to No. 75 in catalogue, was gained by No. 76, a model of single automatic couplings, exhibited by Mr. F. Barnes, of Lower Sydenham. The same exhibitor also received a Prize Medal for No. 119, a double automatic coupling, exhibited in full size fitted on two wagons. We understand that the latter have been running in mineral trains ever since the Exhibition, and have given great satisfaction.

The Great Northern Railway Company intend to apply to Parliament for powers to construct a loop line to its proposed new goods station off Gaol Square, Stafford. The line will commence on and follow the Doxey side of the river Sow for some distance, and will then cross it close to the Corporation Gasworks of Stafford.

The Lancashire and Yorkshire Railway Company is about to extend the roofing at its Southport station, so as to about double the present covered-in accommodation. A large extension is also being carried out at the Preston goods yard, where it is intended to erect large new warehouses. At Bradford extensive sheddings and warehouses are also being put up, contracts for which will shortly be let, and the plans have now been got ready for the superstructure of the Victoria station extension, Manchester.

The Whitby and Loftus Railway is approaching completion. Though only sixteen miles in length it has taken, from one cause or another, some eleven years to complete. In 1871 the first sod was cut by the Marchioness of Normandy, the works being then in the hands of the Middlesbro,' Redcar, and Whitby Railway Company. The line did not progress, however, in their hands, and at length, about four years since, it was bought up by the North Eastern Railway Company, who handed the contract for its completion to that well-known and successful contractor, Mr. John Waddell, of Edinburgh. From the first great difficulties were met with, and the work has tried to the utmost both the skill and patience of Mr. Waddell, and his engineers, Messrs. Mears and Newton. In addition to this, it has proved quite a quicksand in its capacity for absorbing money. The contract price was £154,000, and we understand that already this has been exceeded by at least £30,000. The first station after the line leaves Loftus is Easington, and it was here that the troubles began. A little way past Easington we come to a tunnel, some three-quarters of a mile long. About two years ago, and shortly after its construction, a great landslip occurred at the southern end of the tunnel, by which no less than 100,000 cubic yards of earth were thrown on to the line. The removal of this took a long time, and the work was still further delayed by the necessity which now arose for the construction of a retaining wall to prevent similar slips again. This wall was made 13 ft. 6 in. thick, and carried down to an average depth of 10 ft. below the surface. Leaving the tunnel the road runs with a gradient of 1 in 50 to Staithes, and crosses an iron viaduct 700 ft. long, which carries it 152 ft. above the village beneath. At the other side of the viaduct is the station. Two miles further we come to another station, Hinderwell. Here some considerable labour was incurred by the diversion of the high road twice, once under the railway near the station, and again over the road, by a viaduct, at the other side of the station. Passing Hinderwell, the line runs on past Runswick and Sandsend to Whitby, in many places close to the edge of the cliffs, which are very high here. At Sandsend the embankment is being protected by a sea wall in course of construction. Here also are two tunnels, one short and the other about a mile long. Amongst other difficulties encountered by the contractor was finding water for Hinderwell station. Two wells, one 40 and the other 50 ft. deep, were sunk without success, the latter being deepened to 30 ft. more without any good result. Altogether we should think Mr. Waddell will be glad when the work is off his hands, though, when completed, he will have the satisfaction to be derived from having successfully carried out his contract in spite of all difficulties. The line is likely to pay, despite its expensive construction, as it runs through a country rich in ironstone, and also taps both the agricultural and fishing industries. We hope it may.—*Contract Journal.*

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LIST OF RAILWAY OFFICIALS
UNITED KINGDOM.

Railway.	Miles Open.	General Manager.	Secretary and Assistant Secretary.	Goods and Traffic Manager.	Engineer.	Locomotive Superintendent.	Carriage Superintendent.	Chief Office.
Aylesbury & Buckingham	12¼	J. G. Rowe	J. G. Rowe		William Wilson			Aylesbury.
Ballymena & Larne	30	F. W. Rew	F. W. Rew			W. Pinkerton		Larne Harbour.
Belfast Central	4	J. B. Cooper	J. Ray					41, Coleman-st., E.C.
Belfast & Co. Down	55½	James Barber	J. Milliken		B. D. Wise			Queen's Qy., Belfast.
Belfast & Nor. Co.	136½	Ed. J. Cotton	Charles Stewart	Hugh Ross (Goods)	R. Collins	B. Malcolm	B. Malcolm	York-road, Belfast.
Belfast, Holywood & Bangor	12¼	Joseph Noble	Joseph Noble			A. Ashby		Queen's Qy., Belfast.
Bishop's Castle	9¾	John Craston	William Wilding					Montgomery.
Brecon & Merthyr	61		W. Thompson	A. Henshaw (Traffic)	C. H. Thomas	Charles Long		Brecon.
Bristol Port & Pier	5¾	R. A. Read	J. W. Barton					5, Athenæum, Bristol
Caledonian	704	James Smithells	Archibald Gibson J. L. Maclean	J. Thompson (Goods) I. Kempt (Passenger)	G. Graham, C.E.	George Brittain		302, Buchanan-street Glasgow.
Cambrian	178¼	George Lewis	George Lewis		G. Owen, C.E.	G. Owen		Oswestry.
Carmarthen & Cardigan	19		Alexander Young	A. Young	J. W. Armstrong	Samuel Webber		Carmarthen.
Central Wales & Carm.	13¼	F Grundy	C. J. Hayter			A. Galloway		Carmarthen.
City of Glasgow Union	6¼	Q. Y. Lawson	Q Y. Lawson	Q. Y. Lawson		James Carswell		98, Dunlop-st., G'gow
Cleator & Workington Jnctn	15	T. S. Dodgson	T. S. Dodgson		J. Wood A. H. Strongitharm			Workington.
Cockermouth, Keswick, and Penrith	31½	P. Thompson	Peter Thompson		J. Wood, C.E.			Keswick.
Colne Valley & Halstead	19	John Crabtree	W. G. Bailey					Halstead, Essex.
Cork and Bandon	65		J. H. Connell	Alexander Gordon	J. W. Dorman	Thomas Conran	Thomas Conran	L. Gardiner-st., Dublin.
Cork and Macroom	25		George Purcell	F. L. Lyster		Charles Storer		Capwall Cork.
Cork, Blackrock and Pas.	6½		F. K. Parkinson	T. Warriner (Traffic)	T. Warriner	T. Warriner		Albert-street, Cork.
Cornwall	65½	J. Grierson	Thomas Waghorn F. S. Fowler, Jt.	W. H. Avery (Goods) C. E. Compton (Traffic)	P. J. Margary	W. Dean		Plymouth.
Corris	11	J. R. Dix	J. H. Duncan		J. Kincaid, C.E.	J. R. Dix		Corris, Machynlleth
Cowes and Newport	4¼		John Crick	H. Simmons	H. D. Martin			8, Drapers'-gardens, E.C.
Dublin, Wicklow and W.	136		E. W. Maunsell	W. L. Payne (Traffic)	J. C. Smith	John Wakefield		Westld.-row, Dublin
East and West Junction	40½		C. Banks	J. F. Burke (Traffic)	J. F. Burke			Palace-chamb., S.W.
Festiniog	14¼	C. E. Spooner	C. E. Spooner	F. G. Crick	C. E. Spooner	W. Williams		Portmadoc.
Festiniog and Blaenau	3¾	G. G. Davies	William Davies					Festiniog.
Furness	127	Sir J. Ramsden (Managing D.)	Henry Cook	Henry Cook (Traffic)	F. C. Stileman	Richard Mason		Barrow-in-Furness.
Garstang and Knot End	7	C E. Mounsey	J. Noble			W. Sturzaker		Garstang.
Glasgow and South-Western	332	W. J. Wainwright	J. Morton	D. Dickie (Goods) J. Mathieson (Traffic)	Andrew Galloway	Hugh Smellie		St. Enoch Station, Glasgow.
Great Eastern	834½	W. Birt	Joseph Hadfield	W. Gardner (Goods) J. Robertson (Superdnt.)	A. A. Langley			Liverpool-street.
Great Northern	601	Henry Oakley	Arthur Fitch Wm. Latta (A.)	R. H. Twelvetrees (G.) F. P. Cockshott (Supt.)	R. Johnson T. W. Horn (Ast.)	P. Stirling		King's Cross.
Great Northern, Ireland	467		J. P. Culverwell F. Coates (Asst.)	Thomas Shaw Thomas Cowan Henry Plews	W. H. Mills	James C. Park	J. C. Park	Amiens-st., Dublin.
Great North of Scotland	289¾	W. Moffatt J. S. Stuart (Ast.)	W. Moffatt J. S. Stuart (A.)	A. M. Ross (Goods) A. G. Reid (Passenger)	P. M. Barnett	William Cowan		Aberdeen.
Great Southern & Western (Ireland)	474	G. E. Ilhery	F. B. Ormsby		K. Bayley	A. M'Donnell		Kingsbridge, Dublin
Great Western	2167½	James Grierson	Fk. G. Saunders J. D. Higgins (A.)	H. Lambert (Goods) G. N. Tyrrell (Supernt.)	W. G. Owen	W. Dean	W. Dean	Paddington.
Gwendraeth Valleys	3½	Edward Threlfall	G. Williamson	Henry Smart				Manchester.
Highland	408¼	Andrew Dougall	A. Dougall W. Gowenlock (A)	Thomas Mackay (Gds.) G. K. Ellis (Goods) T. Robertson (Supernt.)	M. Paterson	David Jones		Inverness.
Isle of Man	27	G. H. Wood	G. H. Wood	G. H. Wood	Henry Greenbank	H. R. Hunt	H. R. Hunt	St. Geo.'s-st. Douglas
Isle of Wight	12	Joseph Bourne	R. Hicks	Joseph Bourne	Joseph Bourne	Joseph Bourne		122, Cannon-st., E.C.
Lancashire and Yorkshire	485½	William Thorley T. Collins (A.)	J. H. Stafford D. Norman (A.)	B. Shaw (Goods) J. Maddock (Superndt.)	Sturges Meek	W. B. Wright	F. Attock	Hunt's Bank, Manchester.
Liskeard and Caradon	19½	J. S. Hawker	B. Childs	J. H. Smythurst	J. W. Jenkin	S. W. Jenkin		Liskeard, Cornwall.
London, Brighton & South Coast	413¼	J. P. Knight	Allen Sarle J. J. Moynihan, A	G. W. Staniforth W. J. Williams (Traffic)	F. D. Banister	William Stroudley		London Bridge.
London, Chatham & Dover	153¼	M. Harris A. B. Godhold (Con)	John Morgan	C. H. Chapman (Goods) W. Cockburn (Supernt.)	William Mills	William Kirtley		Victoria Station, Pimlico.
London and North-Western	1716	G. Findlay	Stephen Reay F. Harley (Asst.)	T. Kay (Goods) T. Houghton (A.) G. P. Neele (Superdnt.)	F. Stevenson	F. W. Webb (Crewe) Capt. Dent (Ma.)	R. Bore (Wolverton)	Euston-square.
London and South-Western	793	Archibald Scott	F. J. Macaulay	J. T. Haddow (Goods) E. W. Verrinder (Supt.)	W. Jacomb	W. Adams		Waterloo Bridge.
London, Tilbury & Southend	45	A. L. Stride	John F. Kennell		A. L. Stride	A. L. Stride		Fenchurch-street.
Londonderry & L. Swilly	12	A. H. Stewart	A. H. Stewart	James Stewart	Chas. E. Stewart	P. Ellis		Londonderry.
Lynn and Fakenham	22		C. J. Nicholson	C. L. Tait				Great Yarmouth.
Maenclochog	9		J. B. Macaulay					Clynderwen, R.S.O.
Manchester and Milford	41½	I. Smedley	Wm. Felix Poole		L. R. Wood	L. R. Wood	L. R. Wood	Carmarthen.
Manchester, Sheffield and Lincoln	269	Robert G. Underdown	Edward Ross	Charles Scotter (Goods) W. Bradley (Passenger)	Charle Sacré	Charles Sacré	T. Parkes	London-road, Manchester.
Manchester, South Junction and Altrincham	9¼		R. H. Brown		H. Woodhouse	Charles Sacré		Oxford-road, Manchester.
Maryport and Carlisle	41¼	J. Addison, C.E.	John Addison	John Ellwood (Traffic)	John Addison	Robert Campbell	R. Campbell	Maryport.
Mawddwy	6¾		William Williams	William Williams				Dinas Mawddwy.
Metropolitan	12¾	John Bell	J. M. Eyles		J. Tomlison, Junr.	J. Tomlinson, Jun.		32 Westbourne-tr., W
Metropolitan District	12¾	Lord S. A. Cecil	George Hopwood					6, Westm.-chambers,
Mid-Wales	48½	F. Grundy	J. Wade (London)	J. Grundy	G. F. Ellis	G. F. Ellis	G. F. Ellis	Brecon [S.W.
Midland	1225¼	J. Noble R. Speight (A.)	J. Williams W. E. Blaxter (A)	W. L. Newcombe E. M. Needham (Supt.)	A. Johnston J. Underwood	S. W. Johnson	T. G. Clayton	Derby.
Midland Great Western	425		G. W. Greene	E. B. Ivatts (Goods) J. E. Ward (Traffic)	G. N. Kelly, C.E.	M. Atock	M. Atock	Broadstone, Dublin.
Neath and Brecon	40	F. Kirtley (Neath)	J. E. Griffith		J. E. Medley (Nth.)	J. E. Medley		41, Coleman-st., E.C.
Newport Junction, I. of W.	9	H. Simmons	D. S. Derry	H. Simmons	C. D. Fox			22, Gt. Winchester-st
Newry, Warrenpoint, and Rostrevor	6	T. Smith	Robert Cochran					71, Tower-buildings, Liverpool.
Northampton and Banbury Junction	15	J. W. Theobald	J. W. Theobald	George Porter (Suprnt.)				8, Drapers'-gardens, E.C.
North British	983½	John Walker	G. B. Wieland	D. M'Dougall J. M'Laren (Passenger.)	James Carswell	D. Drummond		Edinburgh.
North-Eastern	1490	Henry Tennant	C. N. Wilkinson	R. Pauling (Goods) A. Christison (Pas.)	T. E. Harrison A. R. C. Harrison H. Copperthwaite W. Cudworth	E. Fletcher (Gateshead)		York.
North London	12	G. B. Newton	G. B. Newton	Thomas Day (Goods) C. L. Templeton (Traffic)	T. Matthews	J. C. Park		Euston Station, N.W.

Railway.	Miles Open.	General Manager.	Secretary and Assistant Secretary.	Goods and Traffic Manager.	Engineer.	Locomotive Superintendent.	Carriage Superintendent	Chief Office.
North Staffordshire	201	M. Smith	Percy Morris	M. Smith	W. H. Stubbs	C. Clare	W. Cross	Stoke upon-Trent.
North Wales	12	R. H. Livesey	R. H. Livesey					Dinas nr. Carnarvon
Oldham, Ashton-under-Lyne and G. B.	6		Edward Ross		Charles Sacré			London-road, Manchester.
Pembroke and Tenbury	27½	I. Smedley	W. F. Poole		L. R. Wood	L. R. Wood	L. R. Wood	Carmarthen.
Ravenglass and Eskdle	7¼	J. Quan		J. Quan		J. Quan		Ravenglass.
Rhymney	42½		William Mein	Cornelius Lundie	C. Lundie	C. Lundie		Cardiff.
Ryde and Newport [side	8½		F. L. Beard	H. Simmons	F. C. Stileman			3, Lothbury, E.C.
Seacombe. Hoylake & Dee	6¾	F. Kirtley	James Ray	F. Kirtley	J. E. Medley	J. E. Medley		41, Coleman-st., E.C.
Severn, Wye & Sevrn. Bridge	37	G. W. Keeling	G. R. Richards		G. W. Keeling			Lydney.
Sligo, Leitrim and Northern Counties	48¼		R. E. Davis	S. B. Humphreys	Henry Tottenham	Henry Tottenham		Manorhamilton.
South-Eastern	364	Myles Fenton M. Tyrwhitt, A.	John Shaw R. Hudson (Asst.)	J. Light (Goods) J. G. Harris (Superdnt.)	Francis Brady J. Barnes (St.'s)	J. Stirling (L.) R. C. Mansell (C)		London Bridge.
Southwold	9	A. C. Pain	A. C. Pain					5, Victoria-st., S.W.
Stafford and Uttoxeter	13¼	J. H. Duffill	C. J. Hayter					Stafford.
Taff Vale	79¼	George Fisher	G. Robertson	James Hurman, Traffic Superintendent.	George Fisher	T. H. Riches	H. O Fisher	Cardiff.
Van	7	J. C. Hughes	W. J. Lavington	J. C. Hughes	W.N. Swettenham			Dashwood House, New Broad-street.
Waterford & Central Ireland	31		W. Williams	W. Williams (Traffic)	C. R. Galwey	D. McDowell		Waterford. [E.C.
Waterford and Limerick	228		M. J. Kennedy	J. Roberts	James Tighe	H. Appleby	H. Appleby	Waterford.
Waterford and Tramore	7¼	William Rea	William Rea		J. Otway	Henry Waugh		Waterford.
Watlington & Prncs. Rishoro'	9	R. W. Lemmon	R. W. Lemmon					Watlington, Oxon.
West Cork	17¾		J. W. Theobald			J. Johnstone		8, Drapers'-gar., E.C.
West Lancashire	7½	T. Gilbert	T. Gilbert		Brunlees and Fox			Southport.
Whitland & Cardigan	16¼	G. Howell	G. Howell	G. Howell	J. B. Walton	G. Howell		Whitland.
Wigan Junction	10	Edward Ross			C. H. Beloe			London-road, Manchester.
Wigtownshire	20¼	Thomas Wheatley	William M'Clure	Thomas Wheatley		T. Wheatley		Wigtown.
Wrexham, Mold., & C's. Q.	16¼	T. Cartwright	J. Fraser		George Owen	F. Willans		Wrexham.
Yarmouth & North Norfolk	24¼	C. J. Nicholson	C. J. Nicholson		C.J. Nicholson, C.E			Great Yarmouth.
Railway Clearing House			P. W. Dawson					Seymour-st., N.W.
Irish Ry. Clearing House			C. A. Clarke					5, Kildare-st., Dublin.
Railway Benevolent Institn.			W. F. Mills					57, Drummond-s.
Railway Building Society			Oliver & Houghton					123 Seymour-st., N.W.

LIST OF RAILWAY OFFICIALS.—India.

Railway.	Miles Open.	Agent.	Consulting Engineer.	Locomotive Superintendent.	Secretary.	Office.
East Indian	1503	Bradford Leslie, Calcutta	A. M. Rendel, M.I.C.E.	D. W. Campbell	A. P. Dunstan	29 and 30, Nicholas-lane, E.C.
Great Indian Peninsula	1439¼	George A. Barnett, B'bay	G. Berkley, M.I.C.E., 57, Charing Cross, W.C.	S. Jackson	T. R. Watt, Managing Director	3, New Broad-street, E.C.
Madras	857	A. M. Saunders	Sir John Hawkshaw, M.I.C.E., F.R.S.	F. H. Trevithick	Julian Byrne	61, New Broad-street.
Bombay, Baroda, and Central India	444	Francis Mathew, Bombay [M.I.C.E.	John Pitt Kennedy, M.I.C.E. (Acting)	E. B. Carroll	T. W. Wood	45, Finsbury-circus. E.C.
Scinde, Punjaub, and Delhi	663	Roscoe Bocquet. C.I.E.	W. J. Kingsbury	W. Sandiford	J. H. Norman	Gresham House, Old Broad-st.
Eastern Bengal	159	Hon. Franklin Prestage, Calcutta	Sir John Hawkshaw, M.I.C.E., F.R.S.	T. Hindmarsh	E. H. Smith	44, Gresham-street, E.C.
Oudh and Rohilkund	546	Lieut.-Col. John Hadow Jenkins	H.B. Hederstedt, M.I.C.E		Major-Gen. C. C. Johnson, Man. Dirctr	29, Martin's-lane, Cannon-st., E.C.
South Indian (Narrow Gauge)	65	William S. Betts	Geo. B. Bruce, M.I.C.E. Charles Douglas Fox, M.I.C.E.	Chas. E. Crighton	H. W. Notman, Managing Director	55, Gracechurch-street, E.C.
Rajputana	400					
Northern Bengal	232					

LIST OF RAILWAY OFFICIALS.—Japan Government Railways.

Directors.	Engineer.	Locomotive Superintendent.	Traffic Manager.	Secretary.	Office.	Agents in London.
Enoye Masaru	C. A. W. Pownall, Principal Engineer Kobe-Otsu Section J. Chambers, Resident Engineer Tokio Section	B. F. Wright, M.I.C.E., Locomotive Superintendent Kobe F. H. Trevithick, A.I.C.S., Locomotive Superintendent, Tokio.	W. F. Page	A. S. Aldrich	Yokohama, Japan	Malcolm Brunker & Co., 22, St. Mary Axe, E.C.
Ihda Toshinori	Engineer in England—William Pole, F.R.S. 31, Parliament-street S.W.					

LIST OF RAILWAY OFFICIALS.—Colonial.

Railway.	Miles Open.	Agent.	Engineer.	Locomotive Superintendent.	Secretary.	Office.
Barbados, Limited			R. F. Fairlie		V. E. Sells	4, Mincing-lane, E.C.
Canada:—						
Buffalo and Lake Huron	162½	(Leased to Grand Trunk	Company.)		T. Short	1, Great Winchester-street-buildings., E.C.
Canada, Southern	323	E. J. Halsey				77, Cornhill, E.C.
Chicago & Grand Trunk, Limited.	330				J. B. Renton	Dashwood House, 9, New Broad-street, E.C.
Grand Trunk of Canada	1406½		E. P. Hannaford	Herbert Wallis	J. B. Renton	Dashwood House, 9, New Broad-street, E.C.
Great Western of Canada	806		J. Hobson	C. K. Domville	W. Lindley	142, Dashwood House, 9, New Broad-street, E.C.
Midland of Canada	160	E. J. Halsey	R. F. Tate	W. B. Ferguson	H. Read	77, Cornhill, E.C.
Hamilton and North Western Northern of Canada	406	Cutbill, Son & De Lungo	O. Jones	J. Webster	W. Townsend	37, Old Jewry, E.C.
St. Lawrence and Ottawa	59		J. G. Macklin	C. Dame	T. A. Welton	5, Moorgate-street, E.C.
Welland	25				H. D. Stead	3, Fenchurch-street, E.C.
Wellington, Grey and Bruce	168⅓	W. Lindley	J. Hobson	C. K. Domville	S. Slater	142, Dashwood House, 9, New Broad-street, E.C.
Windsor & Annapolis (Nova Scotia)	130			P. Innes	W R. Campbell	4, Great Winchester-street, E.C
Cape of Good Hope	970½	Crown Agents for the Colonies.	Charles Hutton Gregory, C.E., C.M.G.			Downing-street, S.W
Ceylon	135	Crown Agents for the Colonies.	Charles Hutton Gregory, C.E., C.M.G.			Downing-street, S.W.
Demerara					V. E. Sells	4, Mincing-lane, E.C.
Jamaica	26	Crown Agents for the Colonies.	Sir J. Hawkshaw, Son & Hayter.			Downing-street, S.W.
Mauritius	87	Crown Agents for the Colonies.	Sir J. Hawkshaw, Son & Hayter.			Downing-street, S.W
Natal	110	Crown Agents for the Colonies.	Geo. Berkley, C.E.			Downing-street, S.W.
New South Wales:— Government Railways	958½	S. Yardley, Secretary, New South Wales Government Agency, 5, Westminster-chambers, S.W.	John Whitton, Engineer-in-Chief, Sydney.		The Commissioner for Railways, New South Wales.	Sydney.
New Zealand:— Government Railways	1287	Agent-General for New Zealand, 7, Westminster-chambers, S.W	Consulting Engineers:— Hemans, Falkiner & Tancred, 2, Westminster-chambers, S.W. John Carruthers, 9, Great Queen's-street, Westminster. Engineers in New Zealand:— John Blackett, North Island. W. N. Blair, Middle Island.		J. P. Maxwell, Gen. Manager in New Zealand.	Public Works Office, Wellington, New Zealand.
Queensland:—						
Western Railway—Brisbane to Roma	319					
Southern Railway—Gowrie Junction to Stanthorpe (This line branches off from the Western line at Gowrie Junction about 108 miles from Brisbane.)	99	Thomas Archer, Agent-General for Queensland.	G. Gemmell Dick, Executive Engineer.		C. S. Dicken	1, Westminster-chambers, Victoria-street, S.W.
Central Railway—Rockhampton to Drummond Range	227					
Northern Railway—Townsville to Reid River	35					
Maryborough Railway — Maryborough to Gympie	0					
South Australia:— Total Miles—645. (Government Railways.)						
Adelaide and Semaphore	9.20					
Adelaide, Hallett and Morgan	202.23					
Hamley, Wakefield, Wallaroo and Snowtown	157.61	Sir Arthur Blyth, K.C.M.G., Agent-General for South Australia, 8, Victoria-chambers, S.W.	H. C. Mais, C.E., Engineer-in-Chief in South Australia.			Government Offices, Adelaide, South Australia
Port Pirie and Jamestown	51.56					
Great Northern	65.27					
Kingston and Narracoorte	52.40					
Rivoli Bay and Mount Gambier	51.20					
Strathalby and Middleton	21					
Goolwa and Victor Harbor	10.40					
Port Broughton & Barunga Range (Private Railways.)	10					
Adelaide and Glenelg	7					Adelaide, South Australia.
Adelaide and Holdfast Bay	7					Adelaide, South Australia.
Trinidad	41 (Besides Tramways.)	Crown Agents for the Colonies.	Charles Hutton Gregory, C.E., C.M.G.			Downing-street, S.W.
Victoria:— Government Railways	1215	The Agent-General for Victoria, 8, Victoria-chambers, S.W.	W. Elsdon, Engineer-in-Chief.	S. Mirls	P. P. Labertouche, Secretary to the Hon. T. Bent, M.P., Commissioner of Railways.	Spencer-street, Melbourne
Western Australia	56	Crown Agents for the Colonies.	Charles Hutton Gregory, C.E., C.M.G.			Downing street, S.W.

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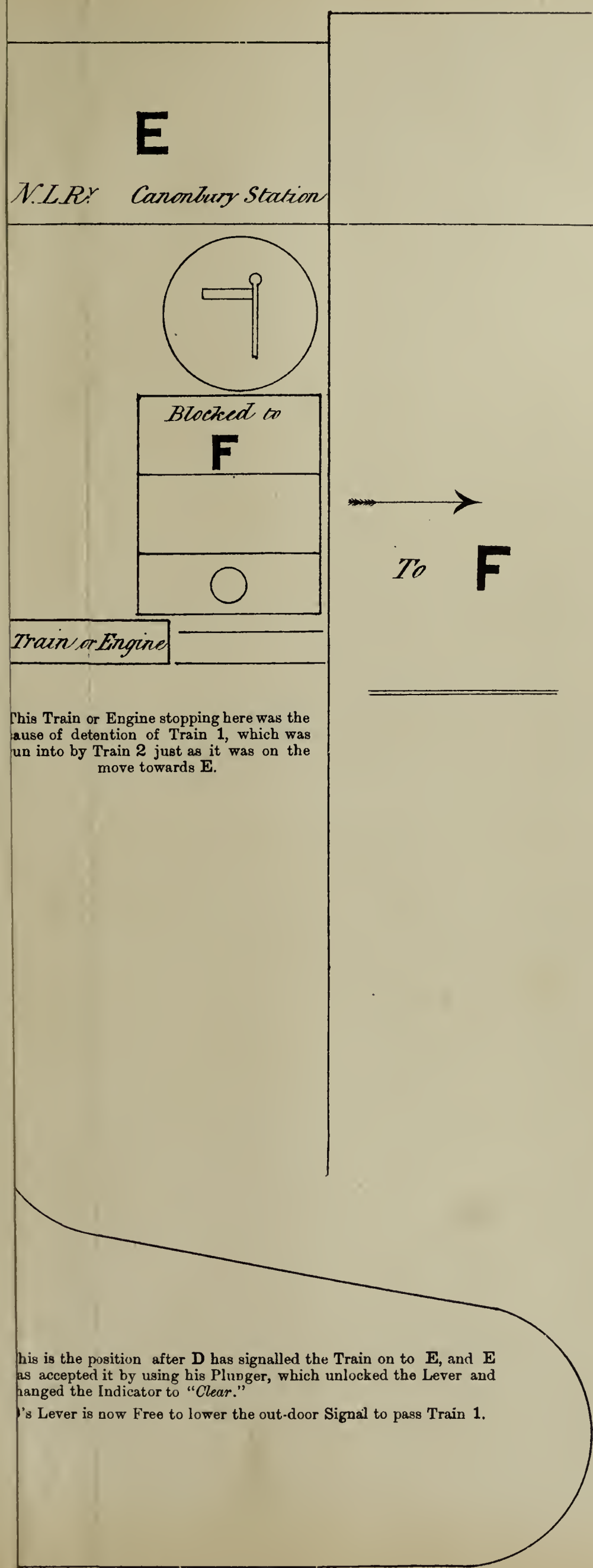
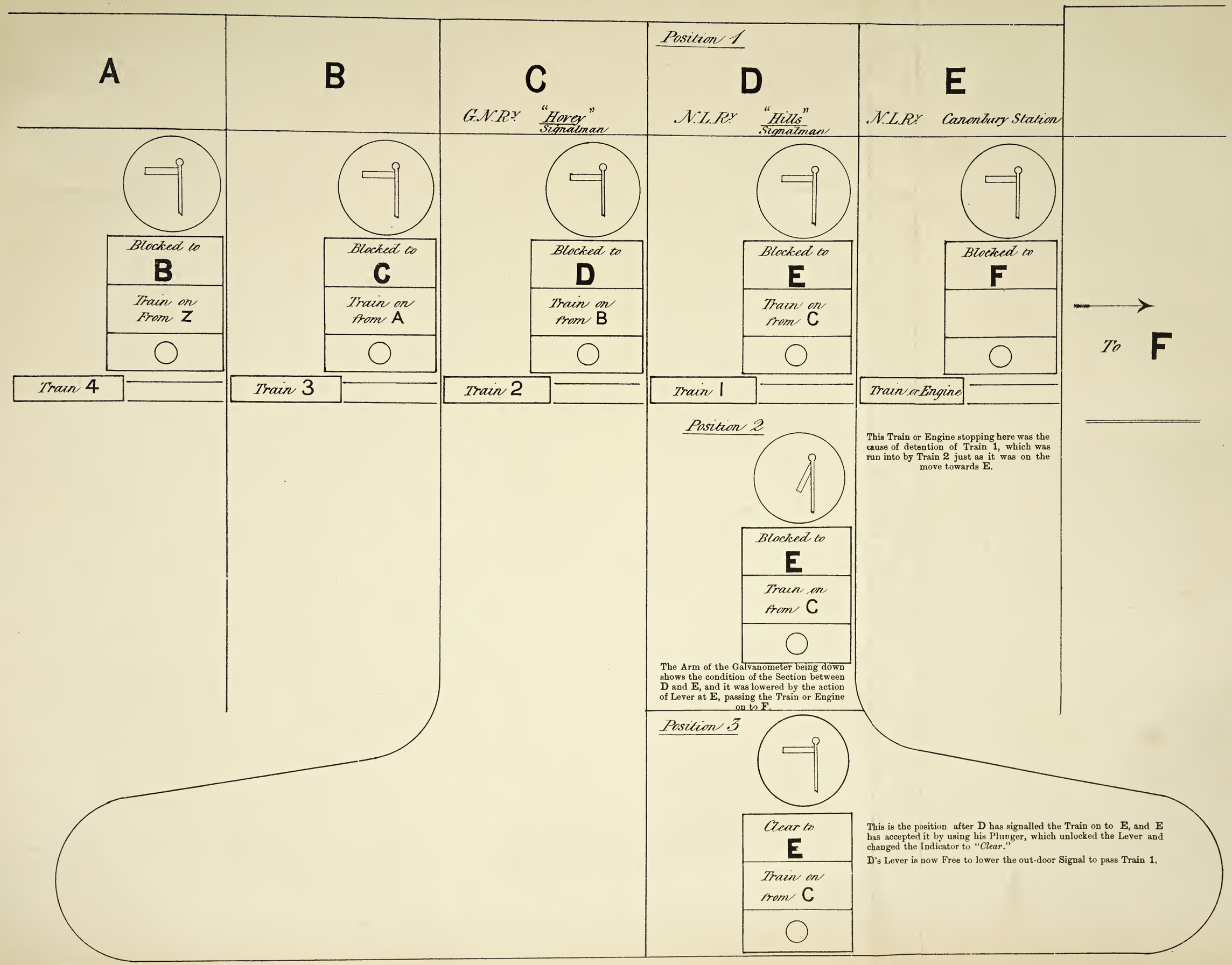
LIST OF RAILWAY OFFICIALS.—CONTINENTAL.

Railway.	Miles Open.	Agent.	Engineer.	Locomotive Superintendent.	Secretary.	Office.
Antwerp and Rotterdam	37¼	G. F. Smith				88, Rue Belliard, Brussels, and 86, Cannon-street, E.C.
Baltic	280½		Schlscbepetoff	Kolshorn	G. Mayer	43, Rue Galernïa, St. Petersburg.
Belgian Eastern Junction		Radcliffe & Co.				20, Craven-street, Cbaring Cross, W.C.
Danube Black Sea	40		G. L. Roff	G. L. Roff	R. Kidner	24, Abingdon-street, S.W.
Dunaburg and Witepsk	161				S. H. Godefroi	15, Angel-court, Throgmorton-street, E.C.
Dutch Rhenisb	133	C. J. Adams	J. Verloop	J. Verloop	J. J. U. Sterling, Utrecht	40, Gracechurcb-street, E.C.
FRANCE:—						
Acbiet and Bapaume			A. Poirel	E. Plocq		Bapaume.
Alais to Rhone & Mediterranean			M. Guillot	M. Froye	R. Frey	10, Place Vendome.
Anvin & Calais			M. Arnoult	E. Plocq	E. Level	18, Rue de Dunkerque.
Arzew and Saida			M. Fousset	M. Grieumard	A. Garnier	47, Rue de Clichy.
Boisleux and Macquion			A. Poisel	E. Plocq	E. Level	18, Rue de Dunkerque.
Bone, Guelma and Extension			M. Krantz	M. Dubos		47, Boulevard Haussmann.
Ceinture de Paris			M. Dubois	M. Gallaud	A. Leo	127, Boulevard Haussmann.
Crecy, Mortiers and Lefere			E. Level	E. Plocq	E. Level	18, Rue de Dunkerque.
Eastern Algerian			M. Scbérer	M. Godard	M. Norès	66, Rue de la Chaussée, d'Antin.
Great Eastern		M. Morrison	M. Durbach	M. Regray	M. Gireaud	5, Rue d'Alsace.
Great Northern	1667	H. E. Lefébure	F. Mathias	E. Delebecque	M. Castel	18, Rue de Dunkerque.
Great Western		W. A. Chaplin	E. Clerc	E. Mayer	A. Frère	110, Rue St. Lazare.
Loire and Haute-Loire			H. Berthord		M. Fouineau	23, Rue de Fleurus.
Medoc		J. Marmont			M. Goutusie	78, Rue d'Anjou Saint Honoré.
Midland			M. Chauvisé	M. Millet	M. Bouvret	11, Massena Passage, Neuilly, Seine.
North-Eastern			E. Cambier			7, Rue Blancbe Paris.
Paris, Lyons and Mediterranean	3555	The Credit Lyonnais	Ruinet du Tailly	Marié	A. Baudin	88, Rue St. Lazare, Paris.
Paris and Orleans			M. Cazavan	M. Forquenot	M. Courras	58, Boulevard des Batignolles.
Picardie and Flanders			Crotet-Parent	M. Kéromnes	M. Lasne	71, Boulevard Ornaro.
Velu-Bertincourt & St. Quentin			M. Grandjean	E. Plocq		2, Place Campion Saint Quentin.
Vetre and Fougères			M. Dornes	M. Dornes	M. Augier	29, Rue Brochant.
Western Algeria			M. Brunie	M. Clerc	M. Helain	27, Rue Brochant.
Grand Central of Belgium	360	G. F. Smith	M. Urban, P. Despret, E. Despret	J. Ryez	V. Stoclet	76, Rue Belliard, Brussels.
Namur and Liege	45					Brussels.
Mons and Mange	21					
Madrid, Saragossa and Alicante	941		J. Ortega	A. Riff	F. Nicholás	Madrid.
Northern of Spain	554	The Credit Lyonnais	E. Plainemaison	E. Bartbelemy	P. M. Vigo	9, Paseo de Recoletos, Madrid.
Ottoman	118¾	I. S. Dalessio, Constantinople	E. Purser, C.E., Smyrna	W. Shotton	S. J. Smithers	Moorgate-street-chambers, 30a, Moorgate-street, E.C.
Riga and Dunaburg	140	F. Robinson	M. Bocker	M. Hentschel	E. Merteus, Riga	Wool Excbange, Coleman-street, E.C.
Royal Sardinian	258	C. De Tivoli and F. G. Whitwham	B. Piercy, C.E.	C. Banfi, Cagliàri	B. Besso, Rome	61, Via Condotti, Rome.
Royal Swedish	45				G. A. Hillier	136, Gresham House, Old Broad-street, E.C.
RUSSIA:—						
Charkoff-Azoff	508¼	Raphael & Sons				Charkoff and 25, Throgmorton-street, E.C.
Charkoff-Krementscbug	170	J. H. Schröeder & Co.		K. K. Huber		St. Petersburg and Leadenhall-street, E.C.
Koursk-Charkoff-Azoff	505½	C. J. Hambro & Son				Moscow.
Kursk-Kiew	293	Raphael & Sons	A. Paskin, Kiew			Charkoff, Moscow and St Petersburg.
Lowzowaia Sevastopol	381	Raphael & Sons	Prohoroff			Simféropol, Crimea.
Morcnansk-Syzran	317	C. J. Hambro & Son		W. Lacklin		St. Petersburg.
Moscow-Jaroslavi	306	Baring Bros. & Co.		W. Schmidt		Moscow.
Moscow-Koursk	332½	Baring Bros. & Co.		P. Klevetsky		Rue Nikolskaia, Moscow.
Orel Jeletz-Griazi	190	Baring Bros. & Co.		R. V. Desen, Orel		St. Petersburg.
Orel-Vitepsk	324¼	I. Thomson, T. Bonar & Co.		N. Chludenew		St. Petersburg.
Rybinsk-Bologoe	185¼	The Russian Bank for Foreign Trade		W. Brunner, Rybinsk		1, Demidoff, Péréoulok, St. Petersburg, & 40, Lombard-street, E.C.
St. Petersburg & Zarkoe-Zelo	17	The Russian Bank for Foreign Trade		N. Peters		St. Petersburg.
Tamboff-Kosloff	44	I. Thomson, Bonar & Co.				57½, Old Broad-street, E.C
Tamboff-Saratov	234	Baring Bros. & Co.		A. Bunge, Saratov		St. Petersburg.
St. Gothard	164		Bridel	Stocker	F. Schweizer, Lucerne	Lucerne, Bellevue.
Sambre and Meuse	86				A. Snellgrove	10, Moorgate-street, E.C.
Smyrna and Cassaba	108	D. Revelaky	O. Redeuil, C.E., Smyrna	F. Peacock	G. A. Cape	8, Old Jewry, E.C.
South Austrian	1390	N. M. Rothschild & Sons (Agents for paying Coupons).		A. Gottschalk, Vienna	A. V. Schrisner, Vienna	Paris and Vienna.
Swedish Central, Limited	61¼	R Mackay	J. Johnson	J. Johnson		3, Lothbury, E.C.
Tournay to Jarbise	47½	J. Cross, London Agent			T. Westwood, Brussels	68, Rue de la Loi, Brussels.
Landen to Hasseit					J. Cross, London	57½, Old Broad-street, E.C.
Varna			G. B. Bidder		J. F. Walsh	8, Great Winchester-street, E.C
West Flanders	102			A. W. Chantrell	F. Smith	10, Moorgate-street, E.C.
Zealand (Denmark)	49	C J. Hambro & Son				70, Old Broad-street, E.C

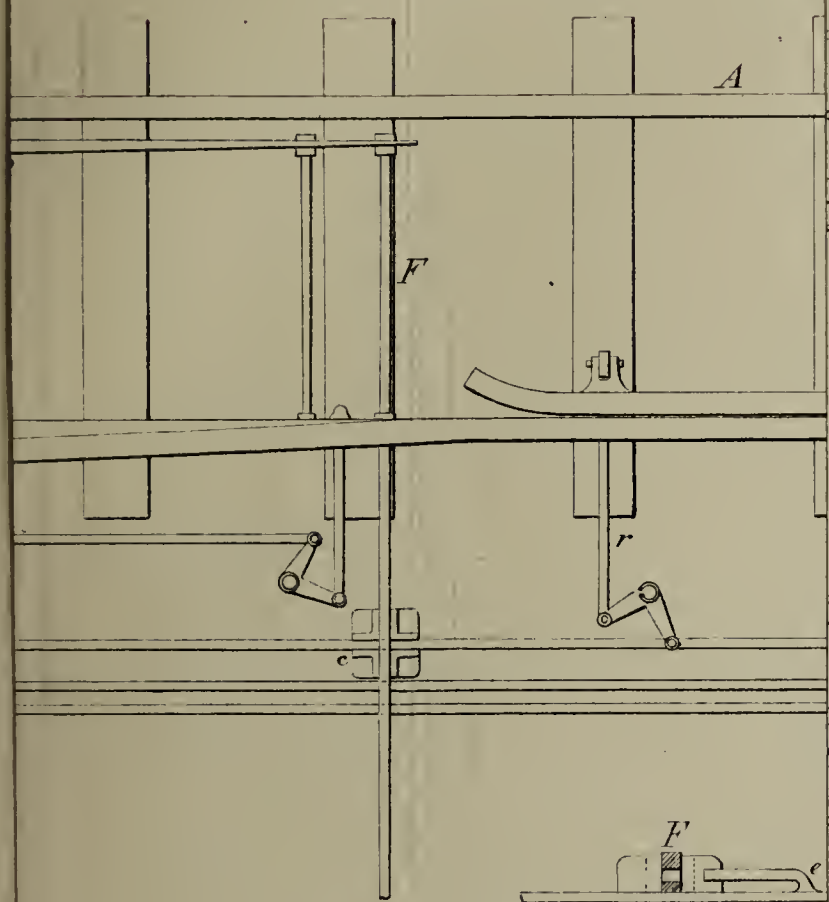

E
N.L.Ry. Canonbury Station
Blocked to
F
To F
Train or Engine
This Train or Engine stopping here was the
ause of detention of Train 1, which was
un into by Train 2 just as it was on the
move towards E.
his is the position after D has signalled the Train on to E, and E
as accepted it by using his Plunger, which unlocked the Lever and
hanged the Indicator to "Clear."
's Lever is now Free to lower the out-door Signal to pass Train 1.

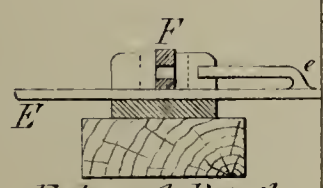
THE RAILWAY ENGINEER.



THE RAILWAY PRINTING & PUBLISHING COMPANY, 12 CRANE COURT, FLEET ST. E.C.

Fig. 154 Stevens' Lock

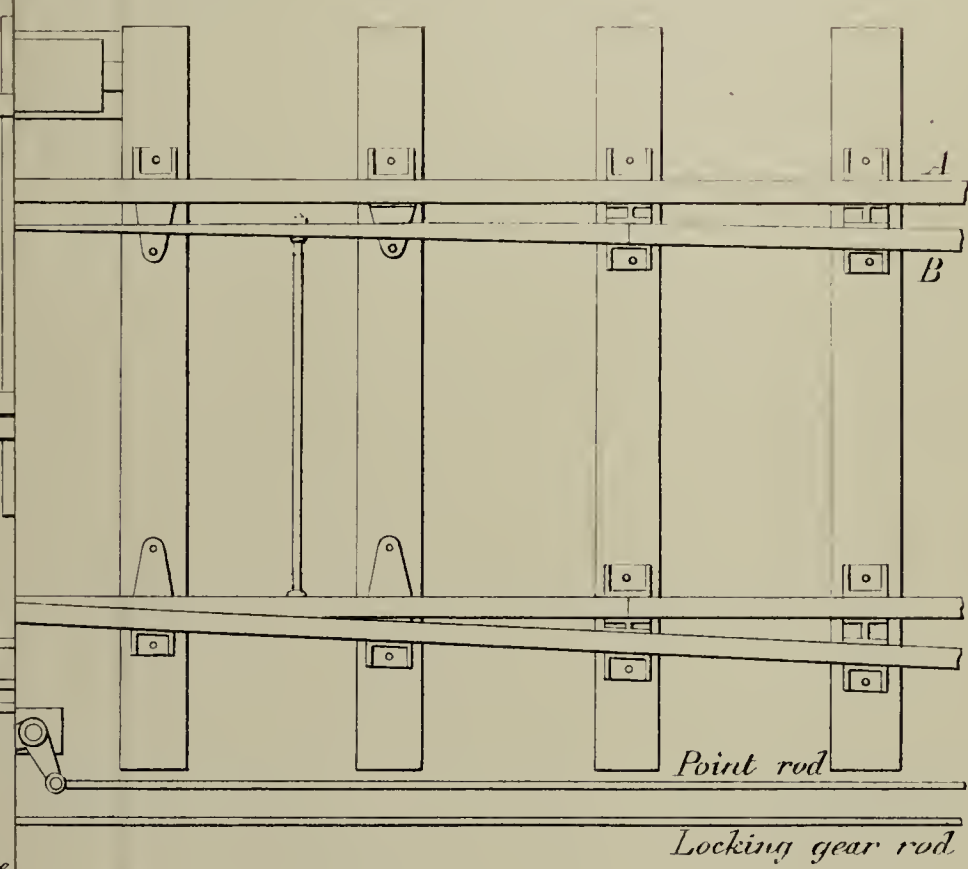




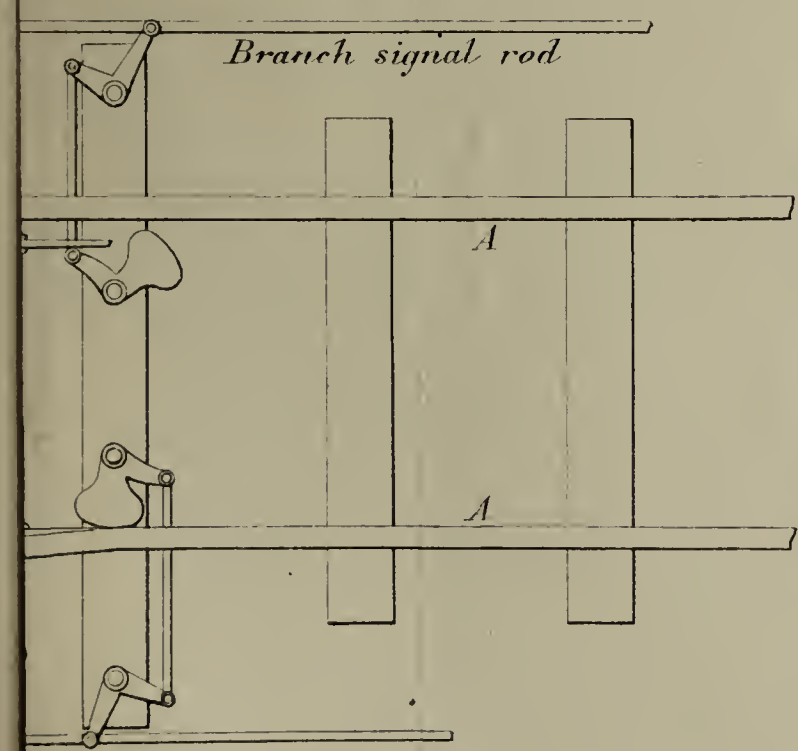
Enlarged Detail

Fig. 156

arison's Lock



. 153



s, and Holland's Lock

axby's Improved Lock

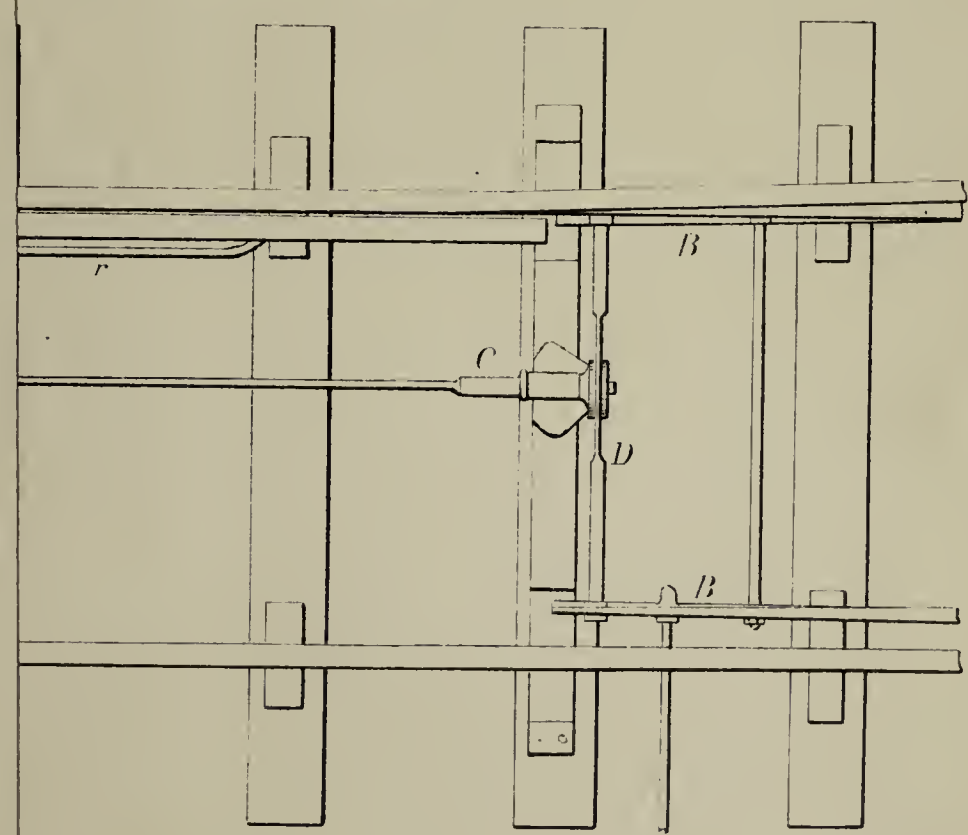


Fig. 155 Kelly's Lock

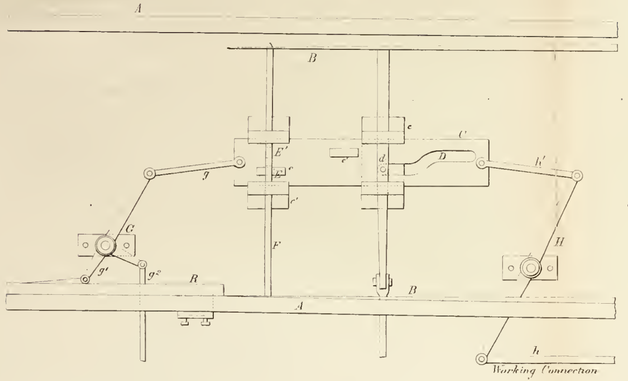


Fig. 149
Bradi's Locking Bar

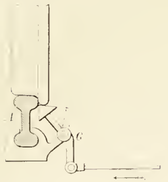


Fig. 150
Buck's Locking Bar

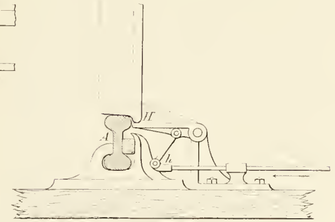


Fig. 154 Stevens' Lock

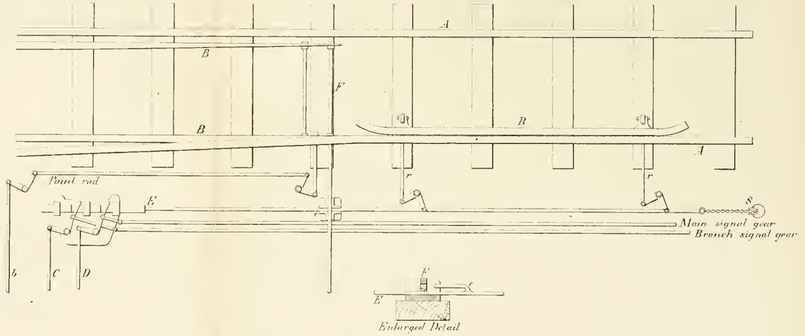


Fig. 156
Harrison's Lock

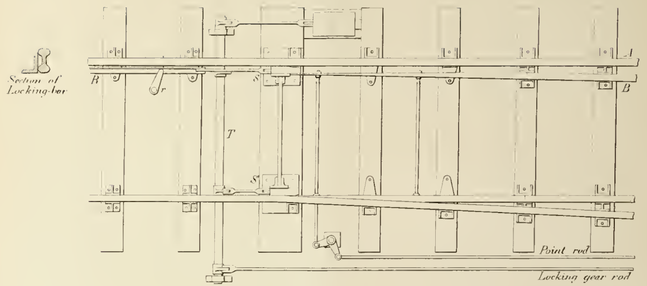


Fig. 152 Saxby's Lock of 1870

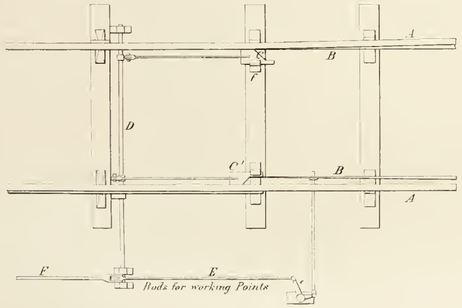


Fig. 154

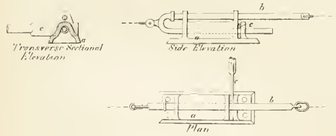
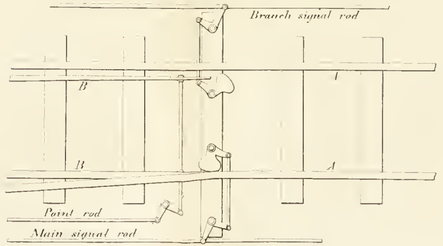


Fig. 153



McKenzie, Clunes, and Holland's Lock

Fig. 157

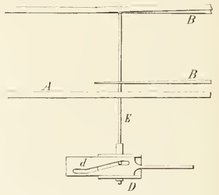
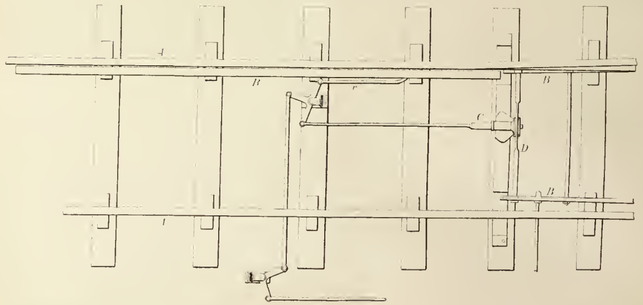


Fig. 159 Saxby's Improved Lock



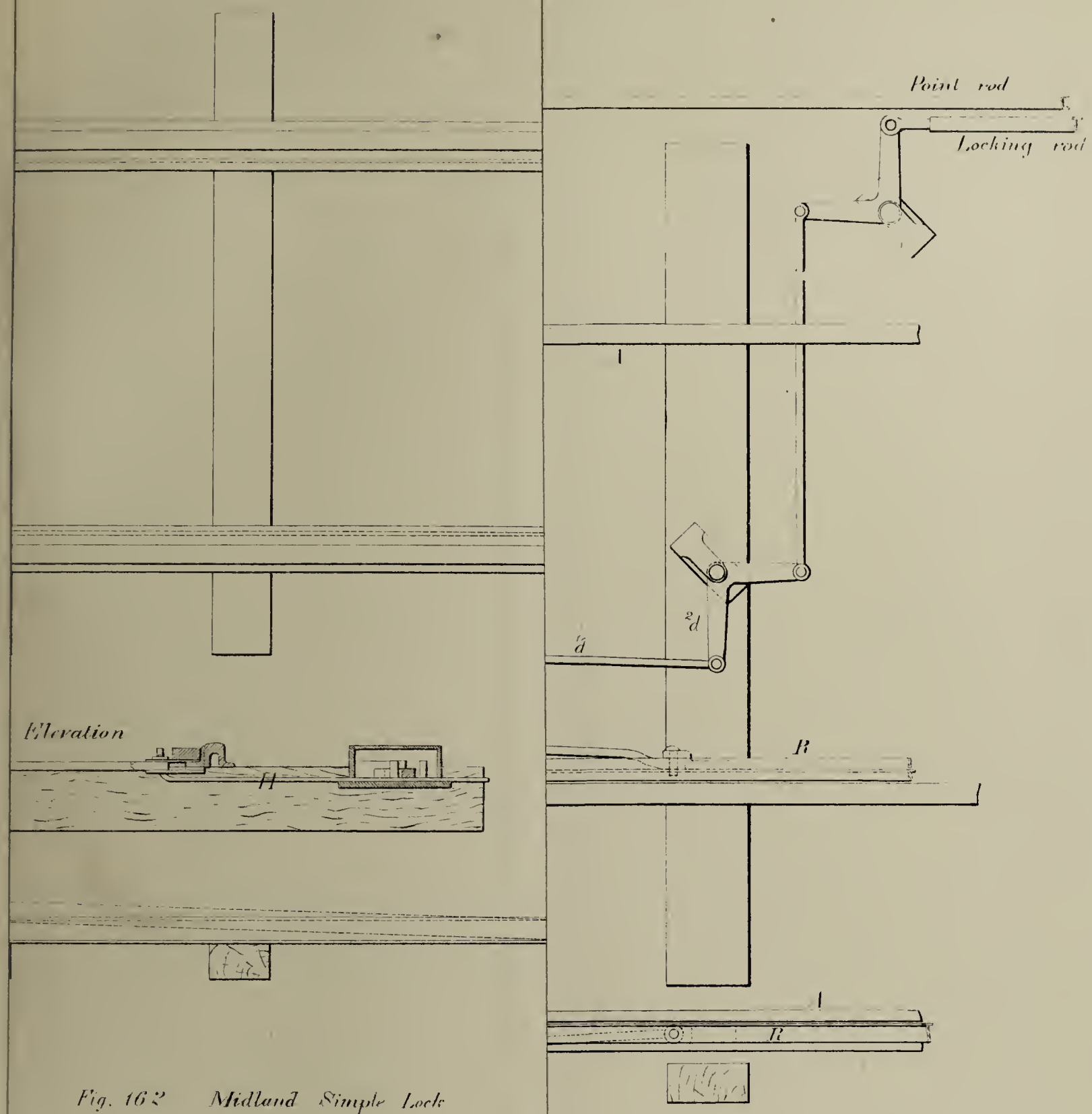


Fig. 162 Midland Simple Lock

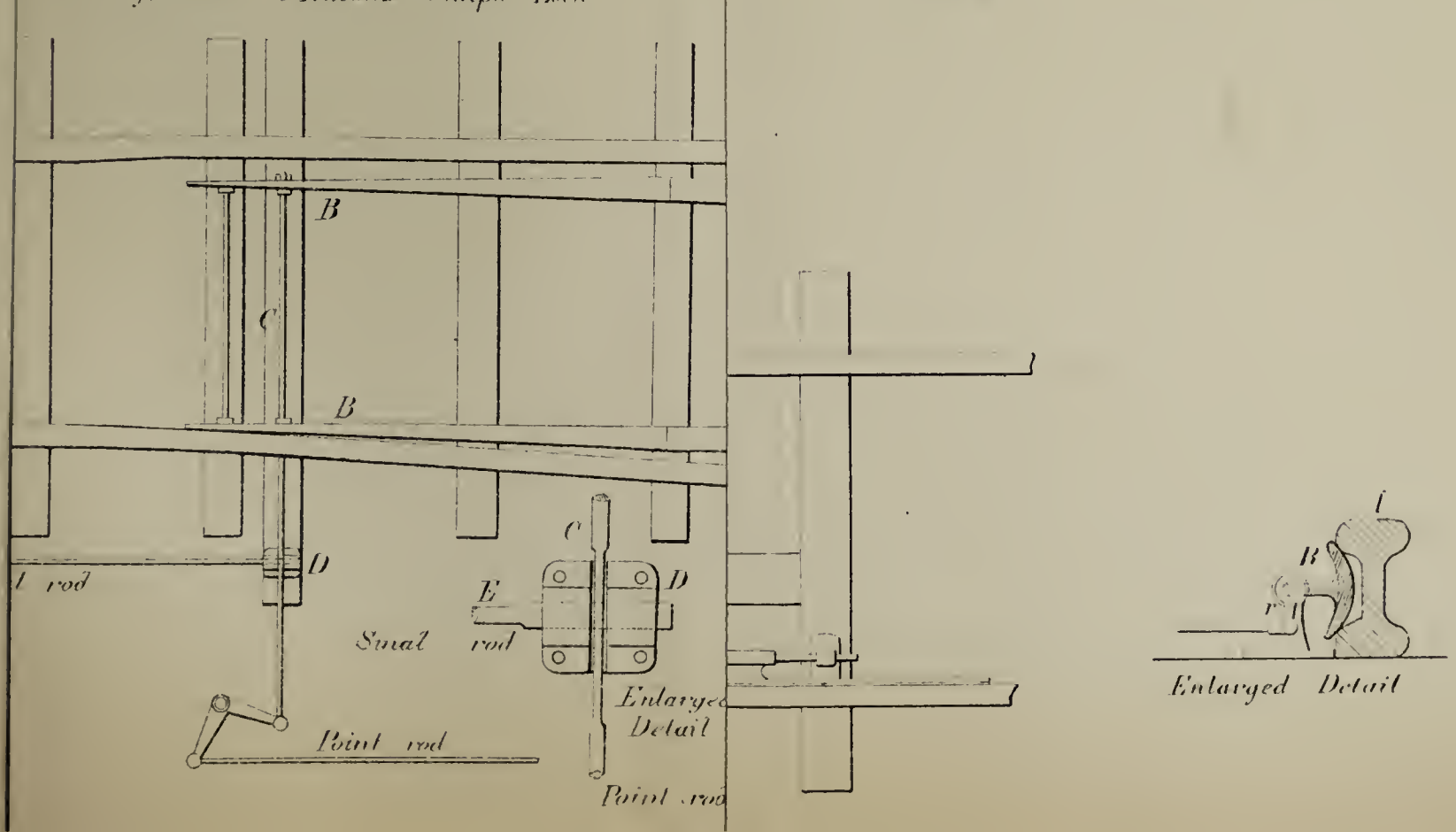


Fig. 158 Bailey's Lock

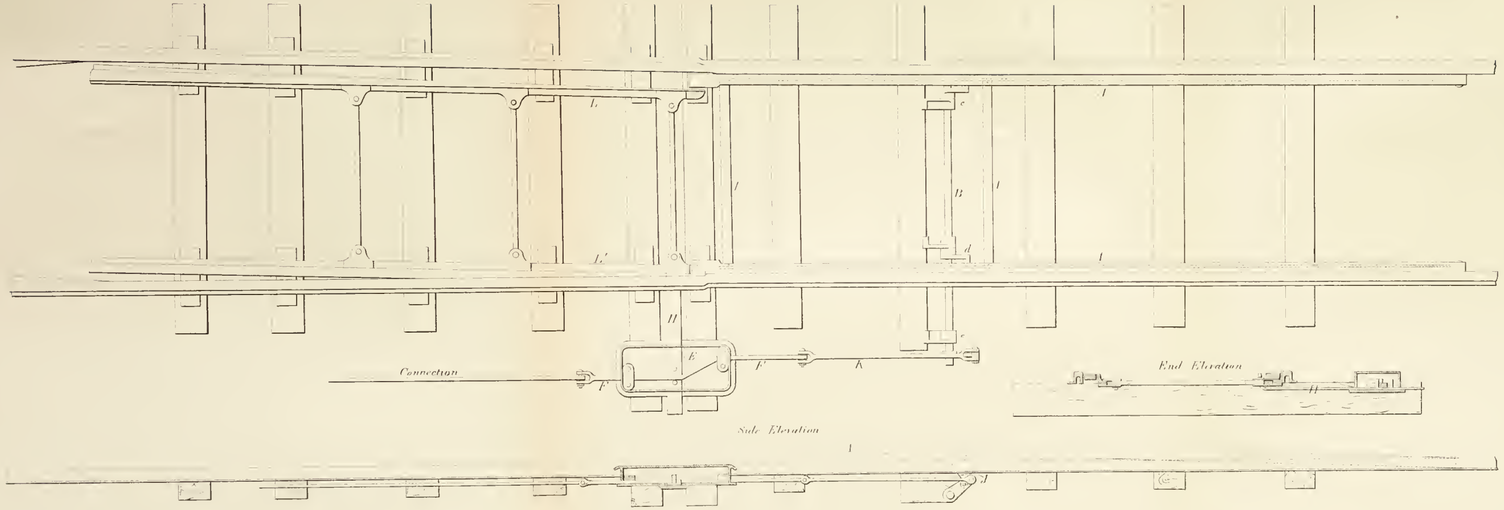


Fig. 161 Webb's Lock

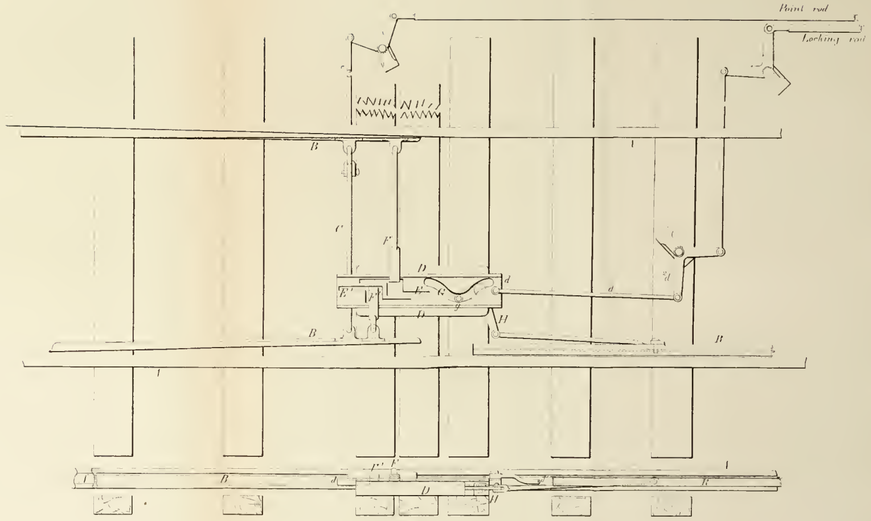


Fig. 161a

Fig. 160 Baker's Lock

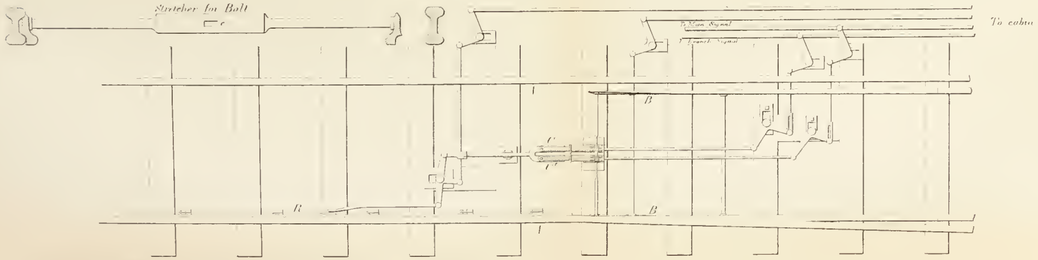


Fig. 162 Midland Simple Lock

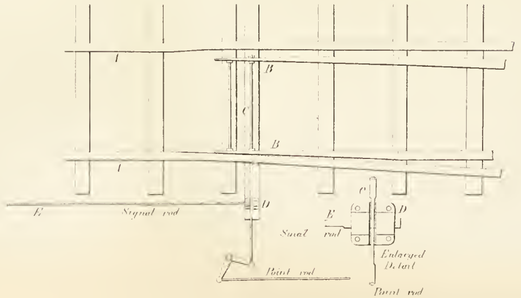


Fig. 163 Brady's Lock

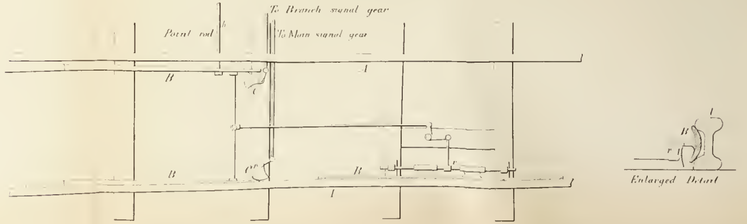


PLATE CXXXV

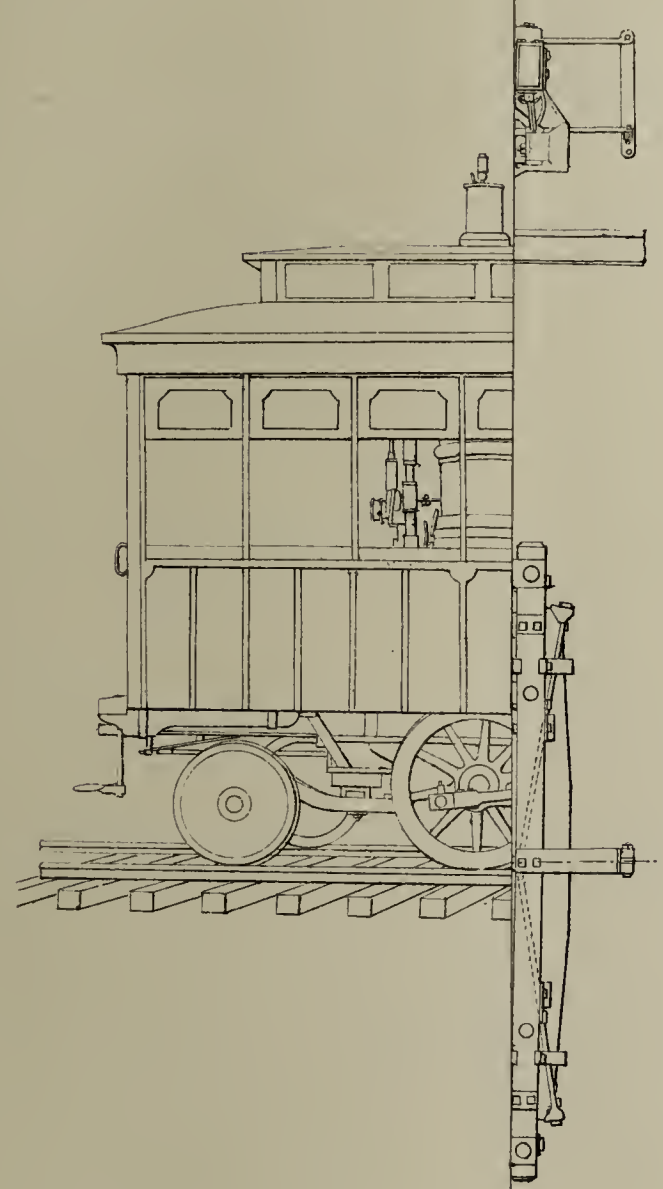


Fig. 11. End View.

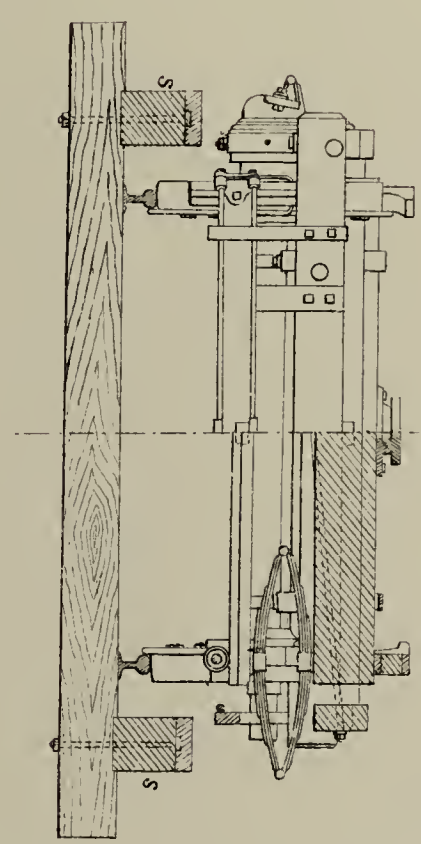
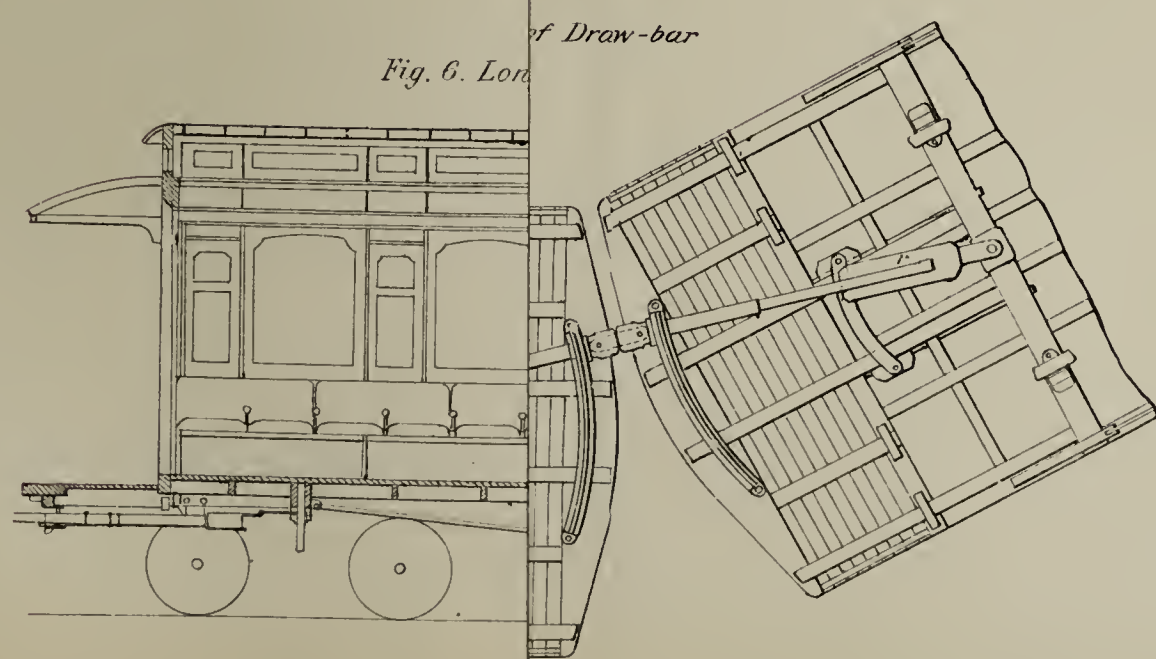


Fig. 12. Section A.B.

Fig. 6. Lon



Viaduct of Second Avenue

Fig 1 Longitudinal Section

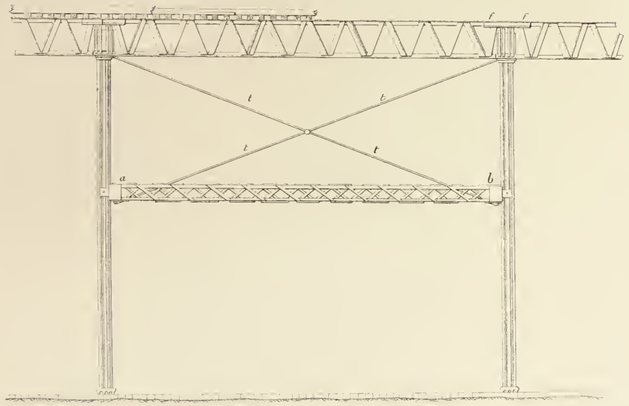


Fig 2. Transverse Section

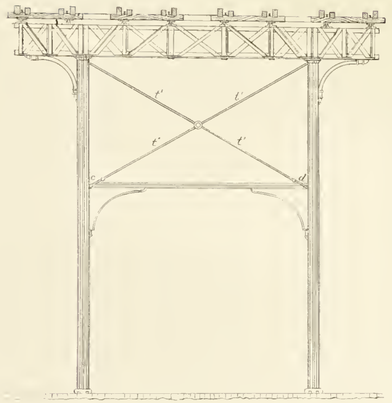


Fig 5. Locomotive.

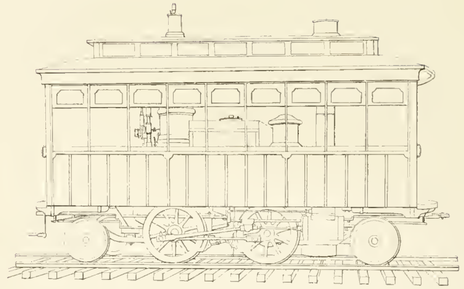


Fig 8. Section C D.

Fig 9 Elevation.

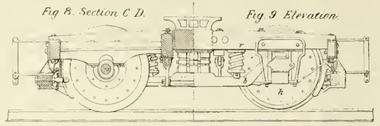
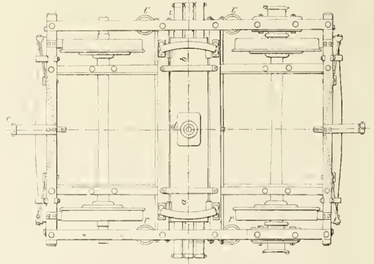


Fig 10 Plan.



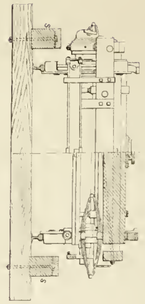


Fig 11 End View

Fig 12 Section A B.

Viaduct of Eighth Avenue

Fig 3

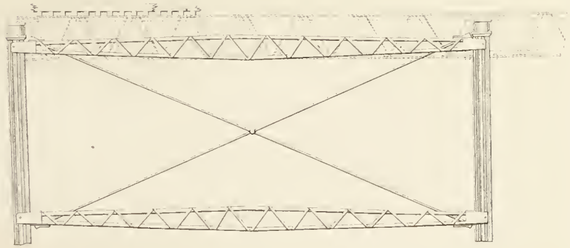


Fig 4.

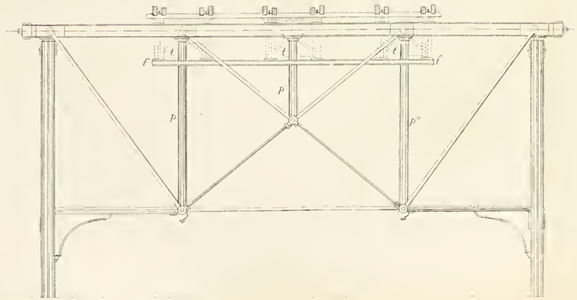


Fig 6. Longitudinal Section

Fig 7 Longitudinal Elevation

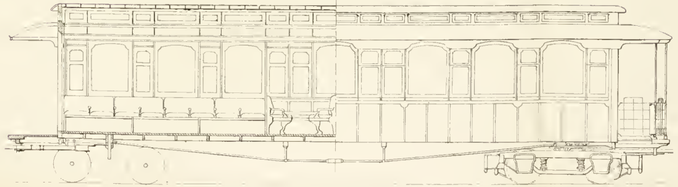


Fig. 13. Plan of Draw-bar

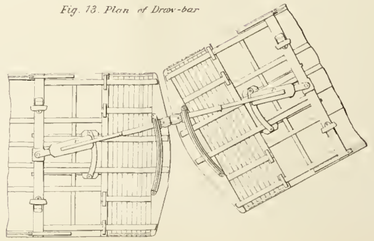


Fig. 168 Saxby & Farmer's Lock & Detect

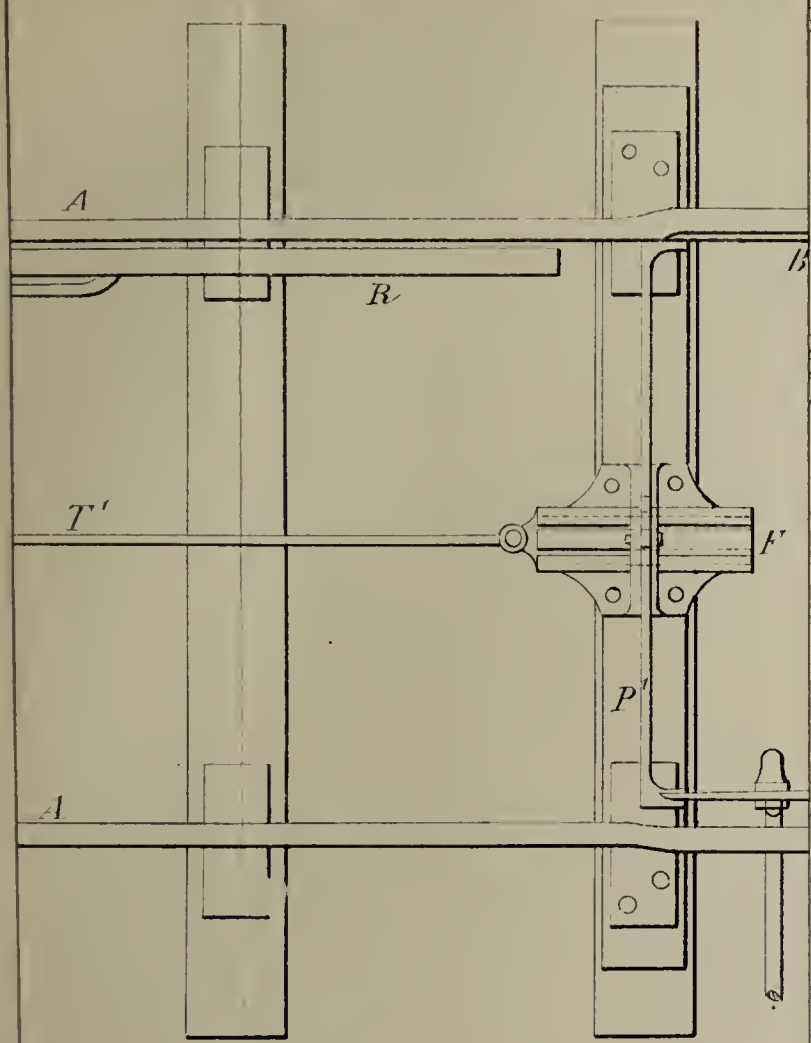


Fig. 168 b

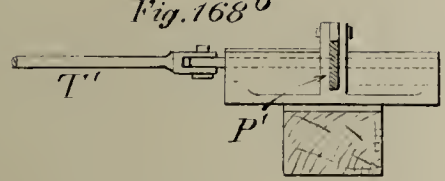


Fig. 172 Edward's Lock

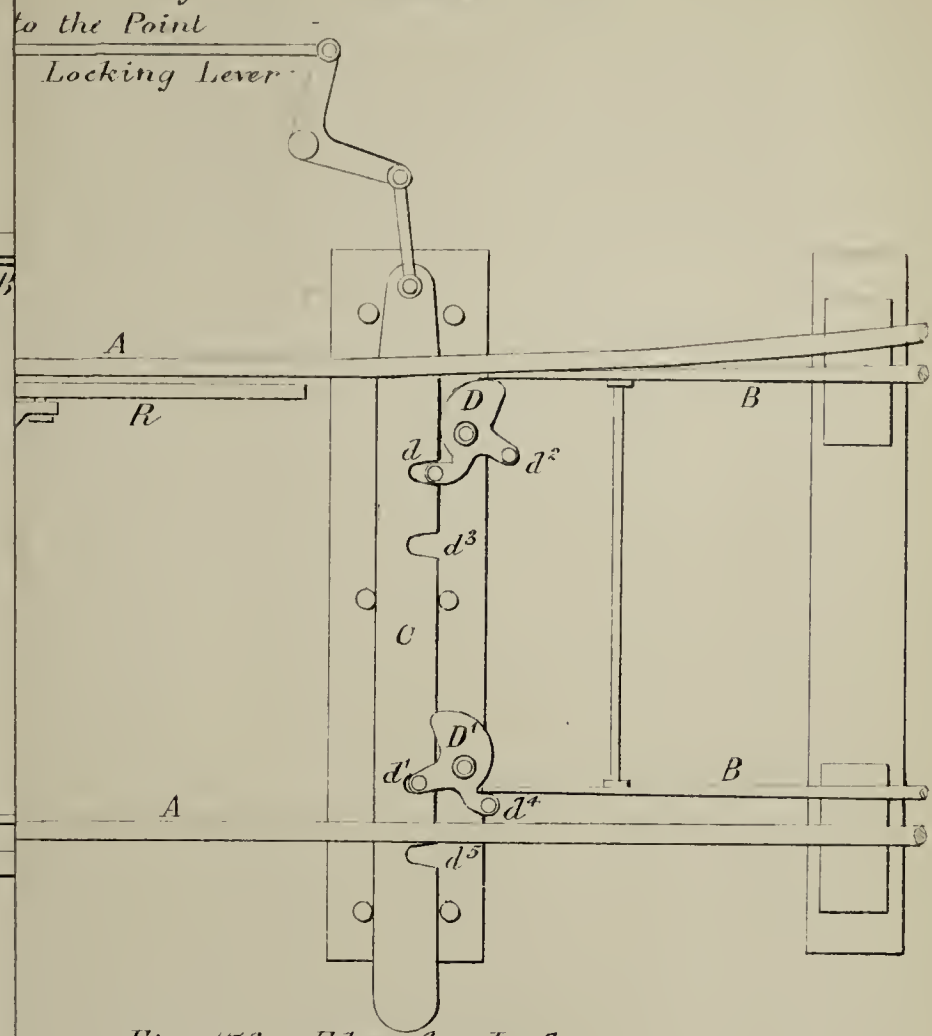
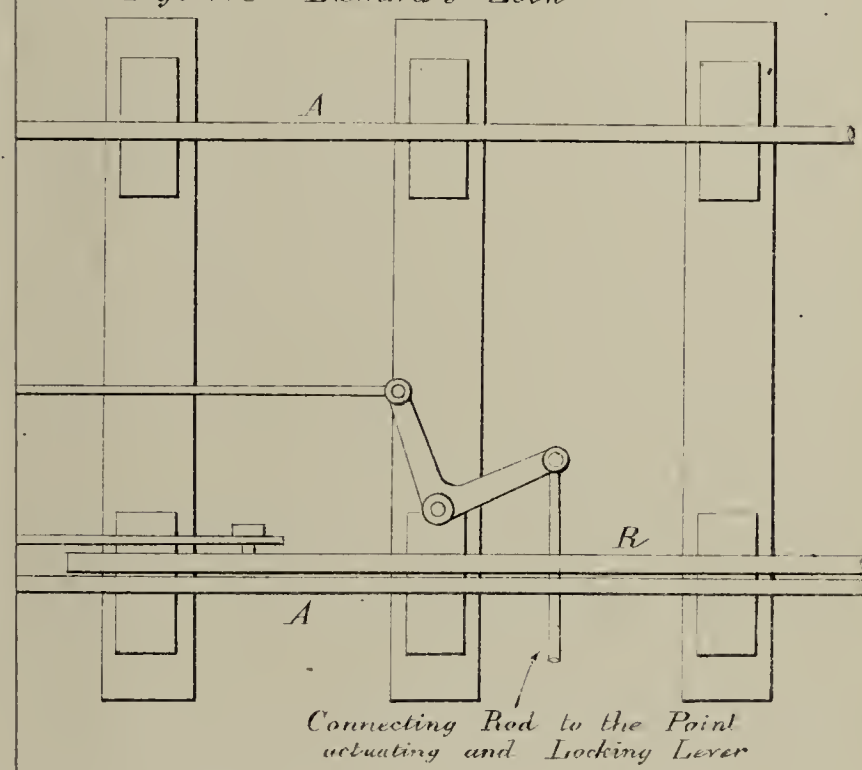


Fig. 173 Edward's Lock



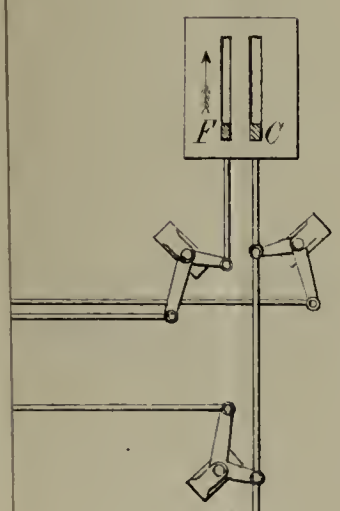


Fig. 175

Saxby & Farmer's Improved Point Lock and Indicator

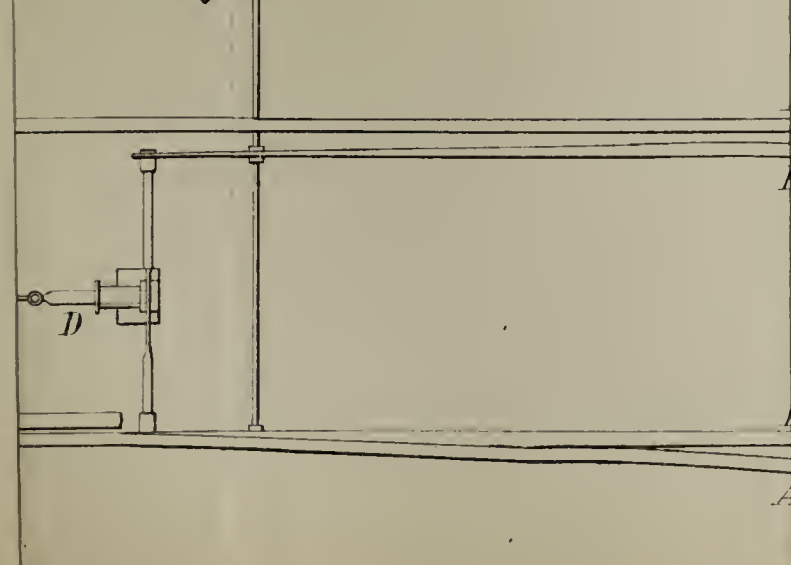
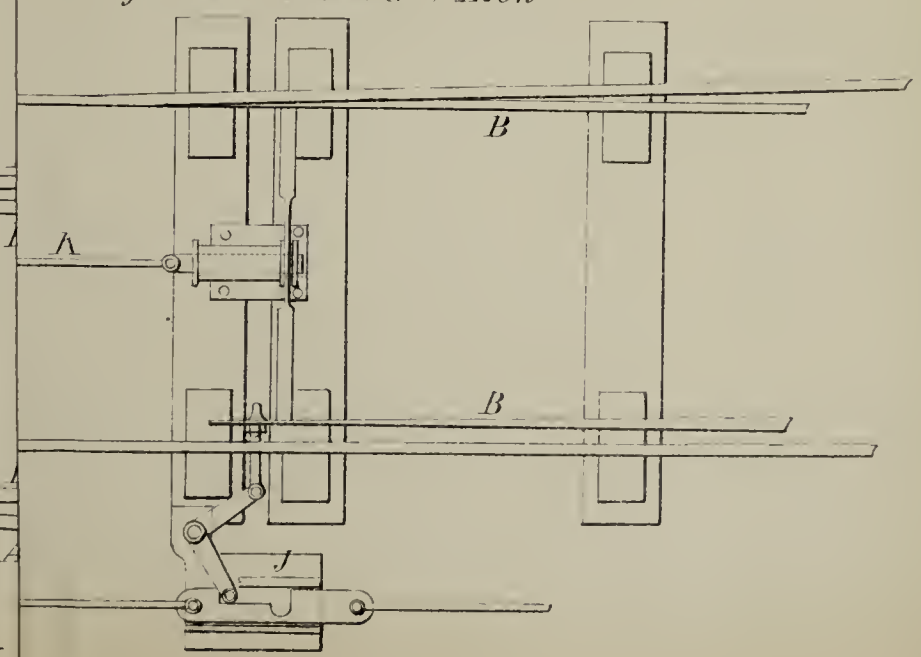


Fig. 174 Edward's Lock



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THE RAILWAY ENGINEER.

Rapier's Lock

Fig. 164

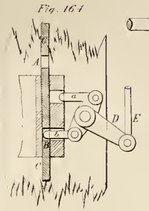


Fig. 165

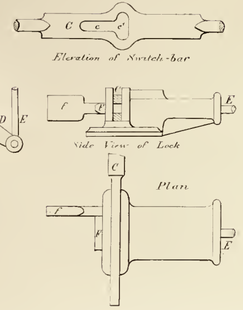
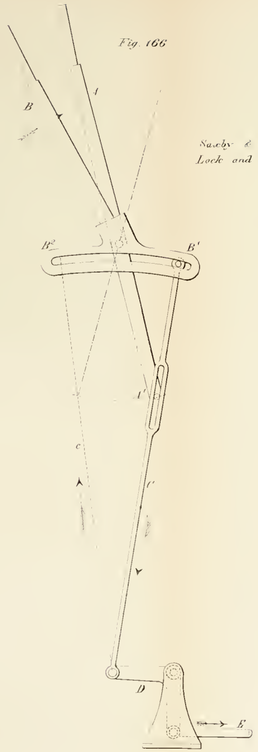
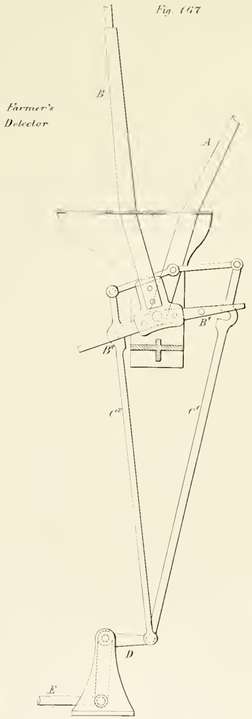


Fig. 166



Saxby & Farmer's Lock and Detector

Fig. 167



Saxby & Farmer's Lock & Detector

Fig. 169

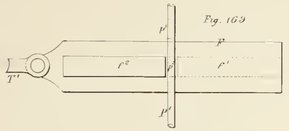


Fig. 170

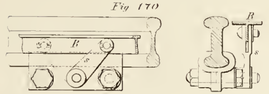


Fig. 171

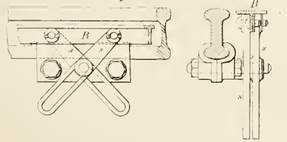


Fig. 168 Saxby & Farmer's Lock & Detector

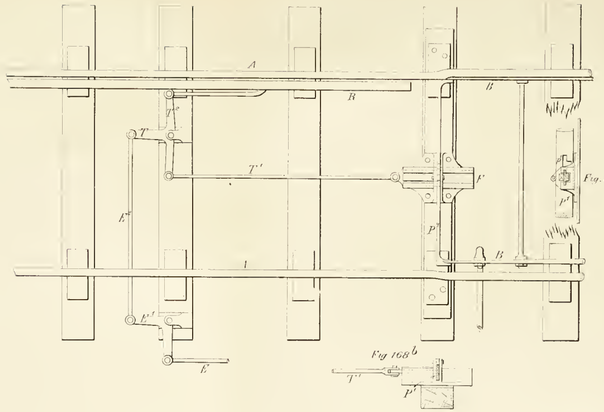


Fig. 168a

Fig. 168b

Fig. 175

Saxby & Farmer's Improved Point Lock and Indicator

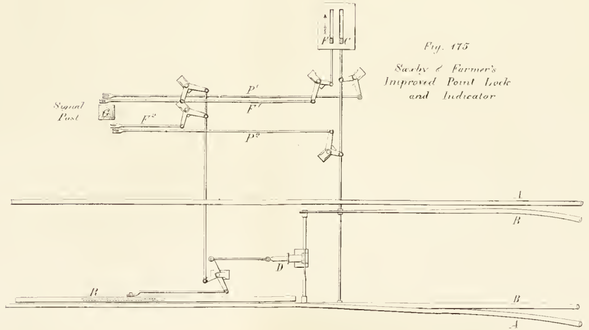


Fig. 176

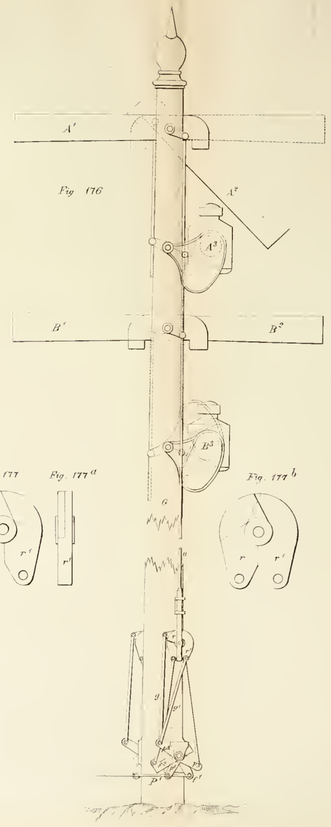


Fig. 177 Fig. 177a Fig. 177b

Fig. 172 Edward's Lock

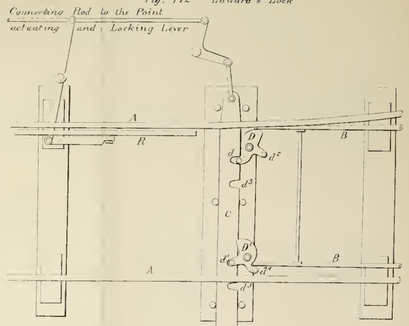


Fig. 173 Edward's Lock

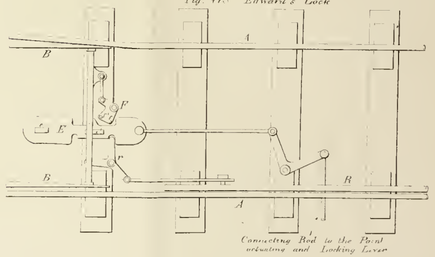
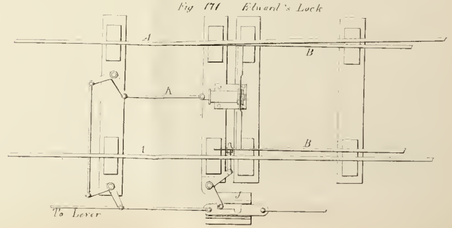


Fig. 174 Edward's Lock



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THE RAILWAY ENGINEER.

Fig 178 Annett's Lock for Outlying Points

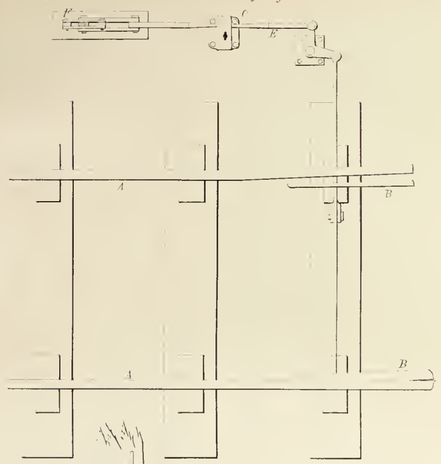


Fig. 179

Fig. 186

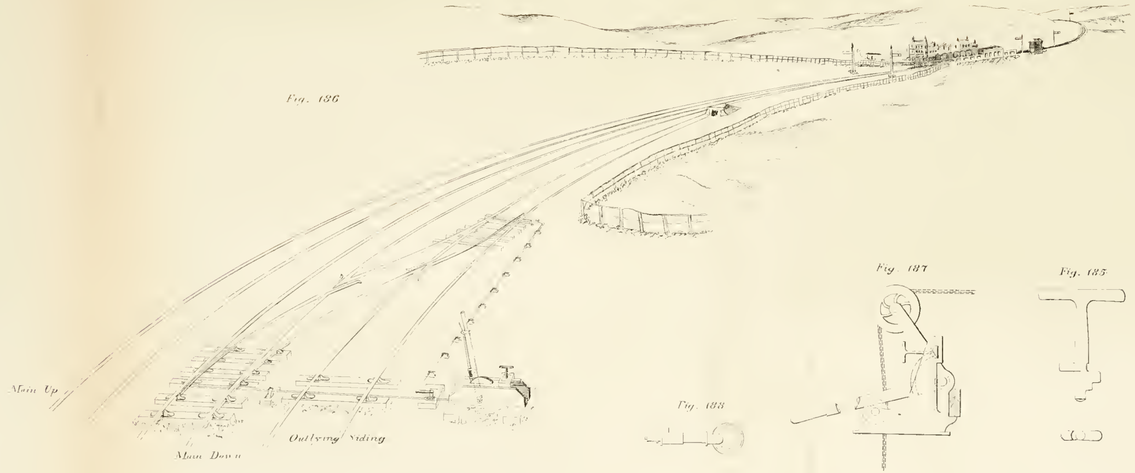
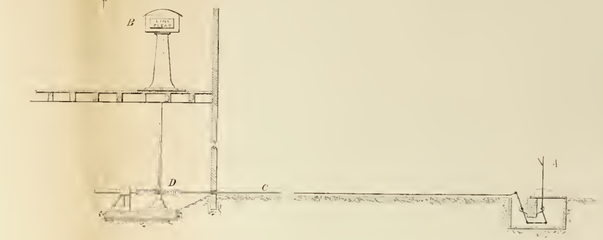


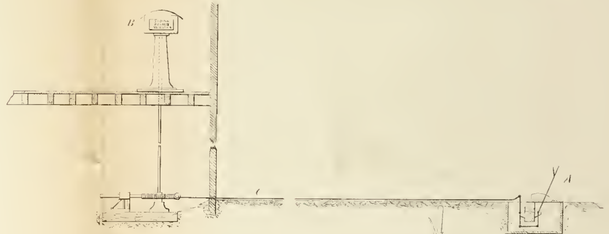
Fig 187

Fig. 185

Fig. 188

Fig. 189





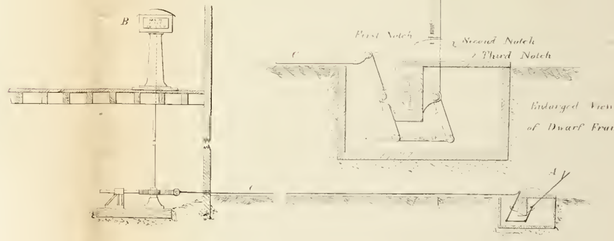


Fig. 190

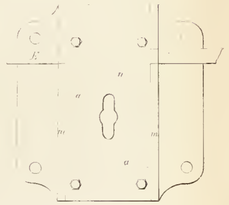


Fig. 191

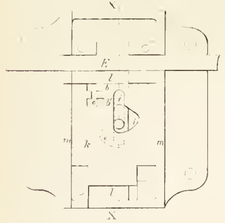


Fig. 192

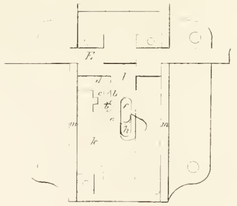


Fig. 193

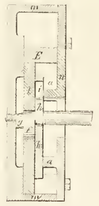


Fig 194

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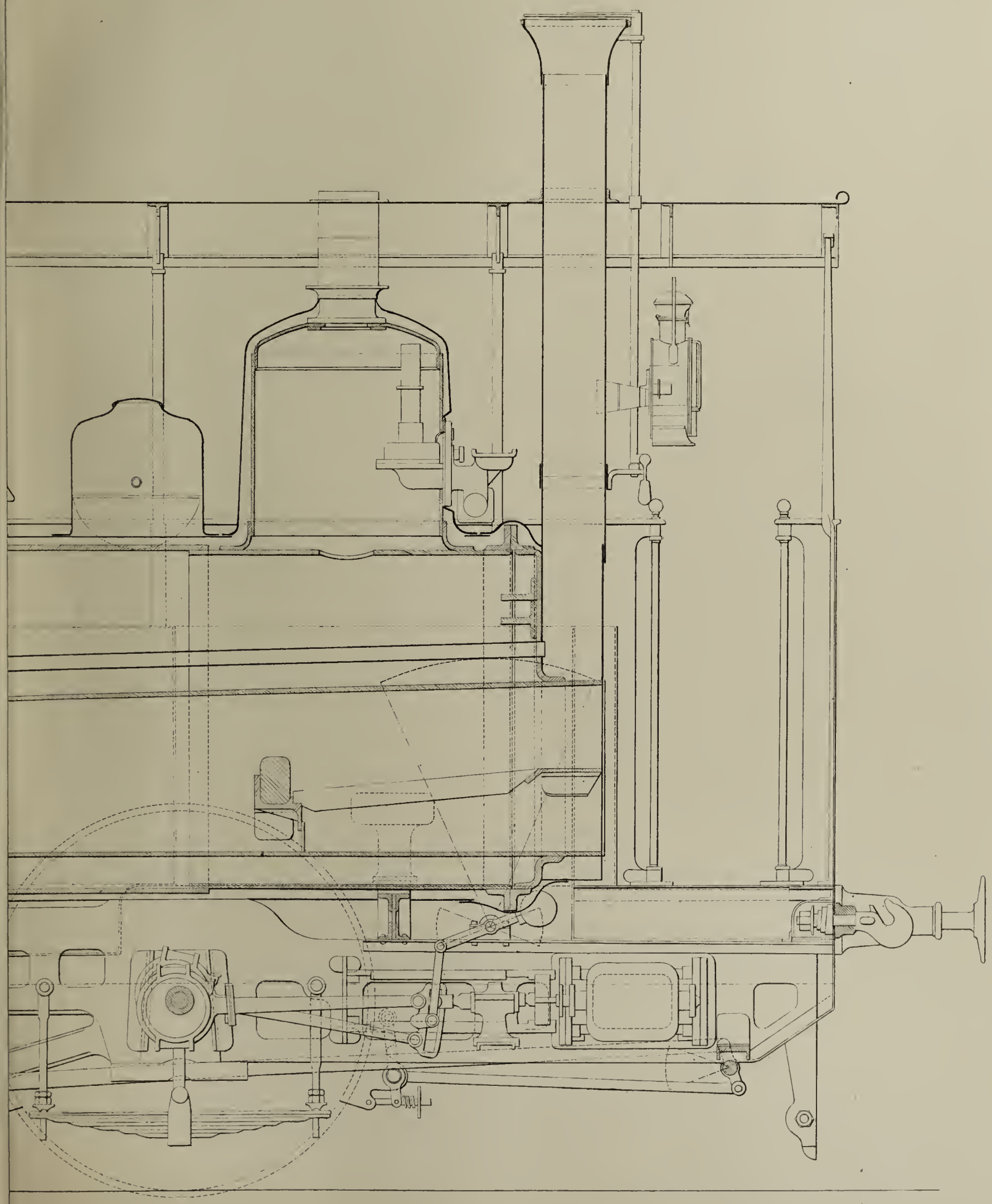
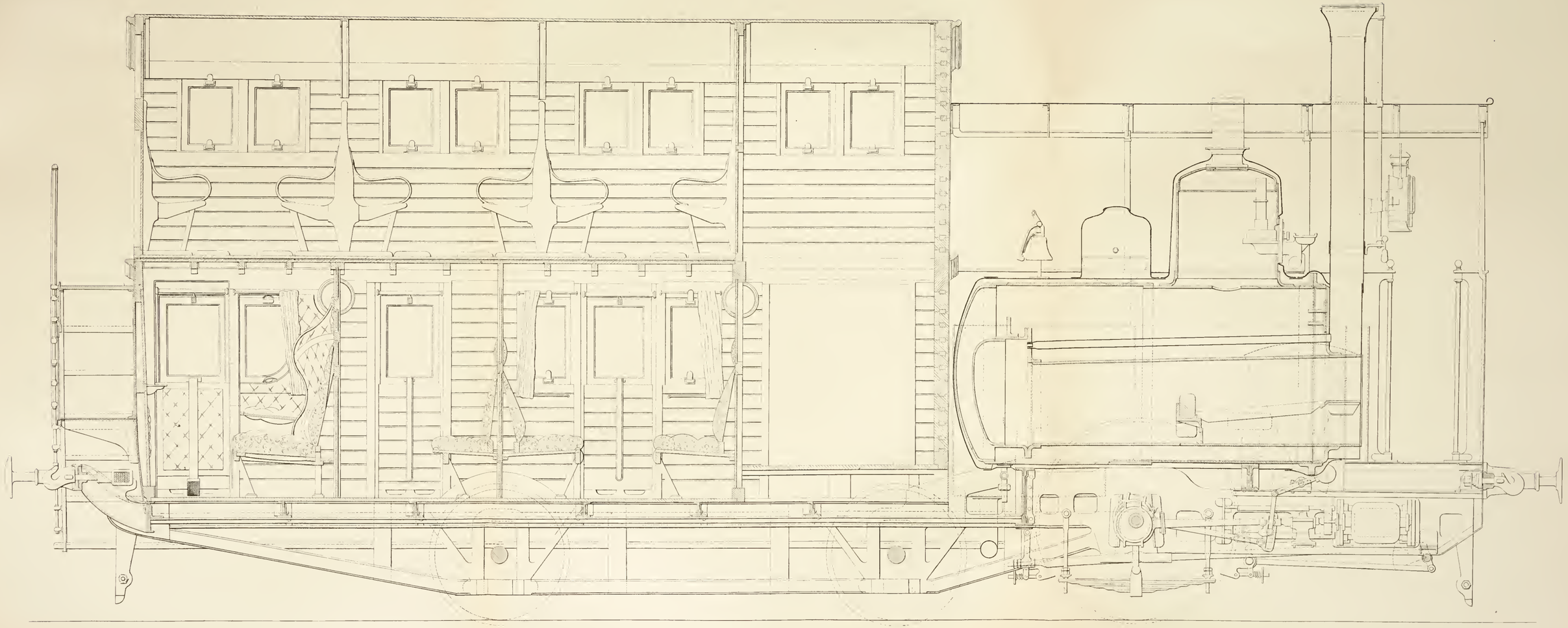
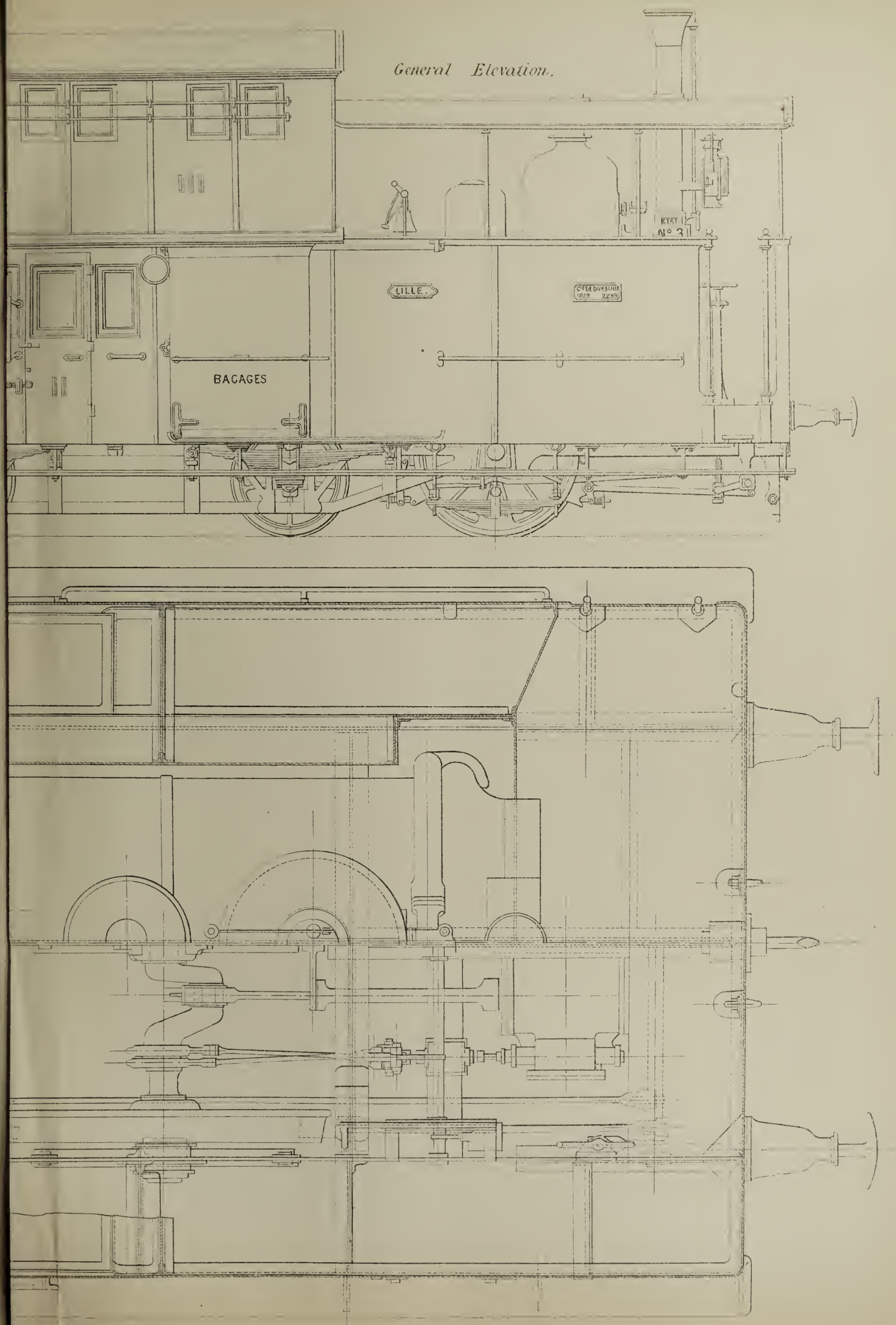


THE RAILWAY ENGINEER.



THE RAILWAY PRINTING & PUBLISHING COMPANY 12 CRANE COURT, FLEET STREET E.C.

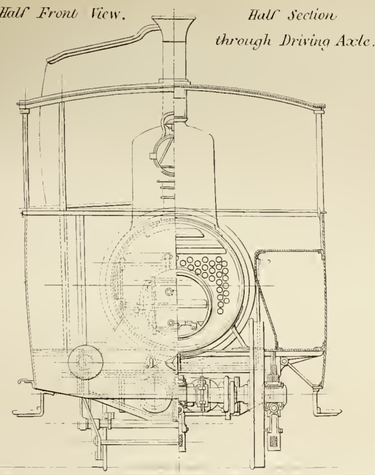

General Elevation.
ETAT
N° 3
LILLE.
BAGAGES

THE RAILWAY ENGINEER.

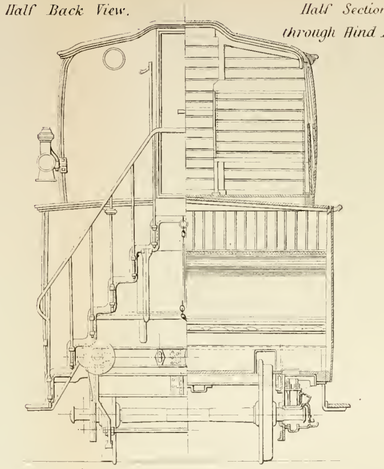
LIGHT RAILWAYS

STEAM CARRIAGE OF FRENCH STATE RAILWAYS

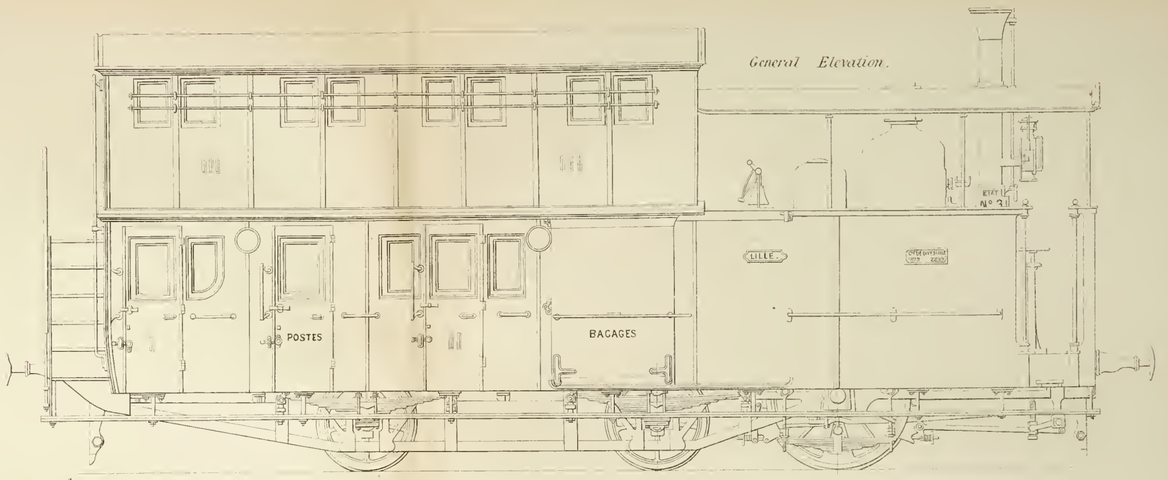
Half Front View. *Half Section through Driving Axle.*



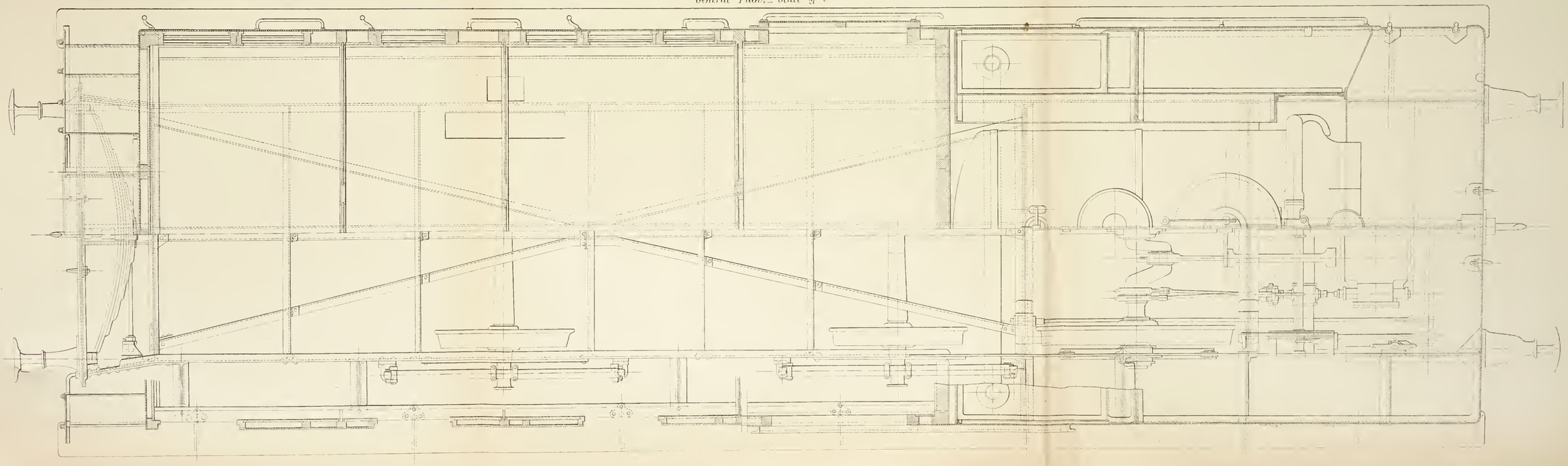
Half Back View. *Half Section through Hind Axle*



General Elevation.



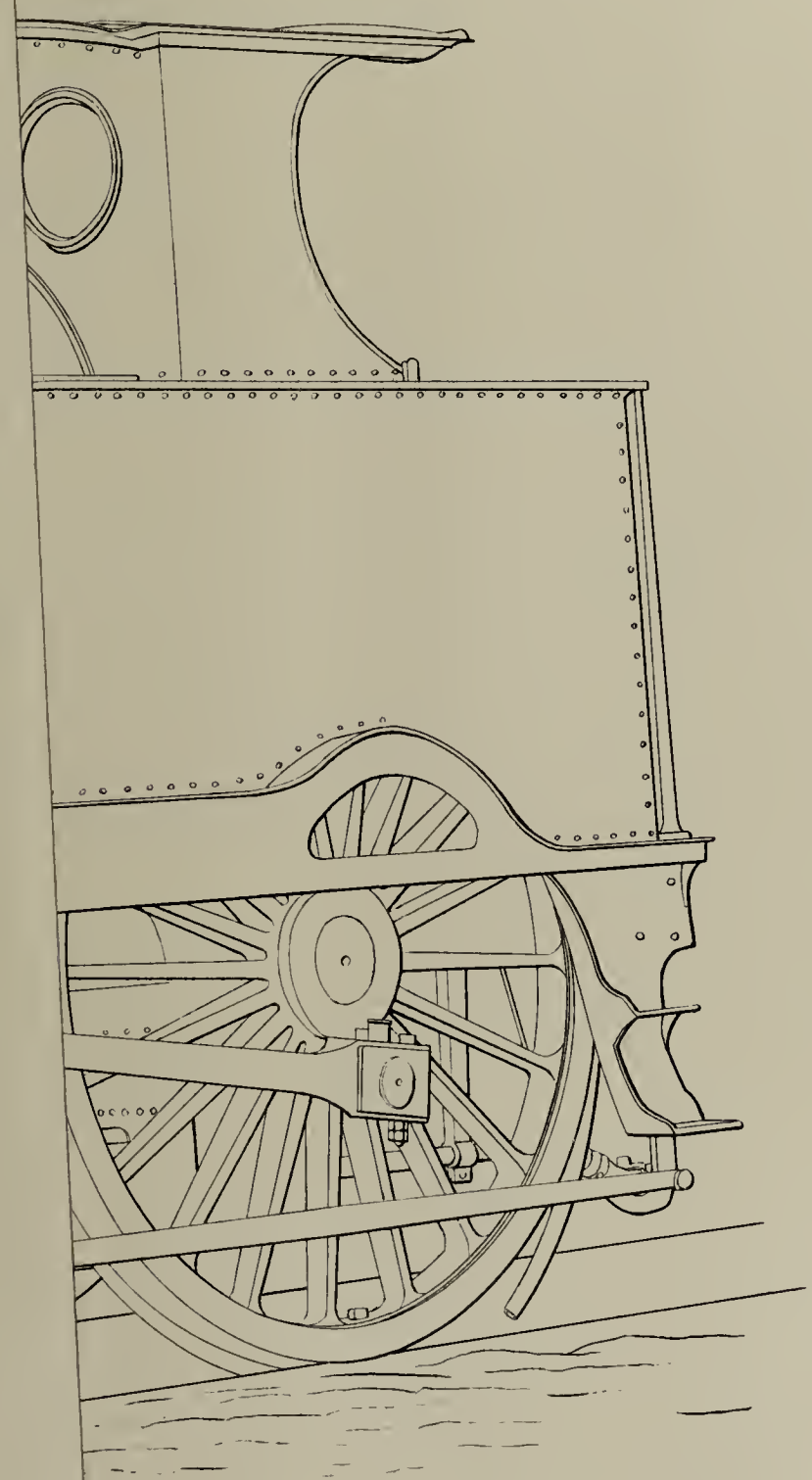
General Plan.— Scale $\frac{1}{24}$



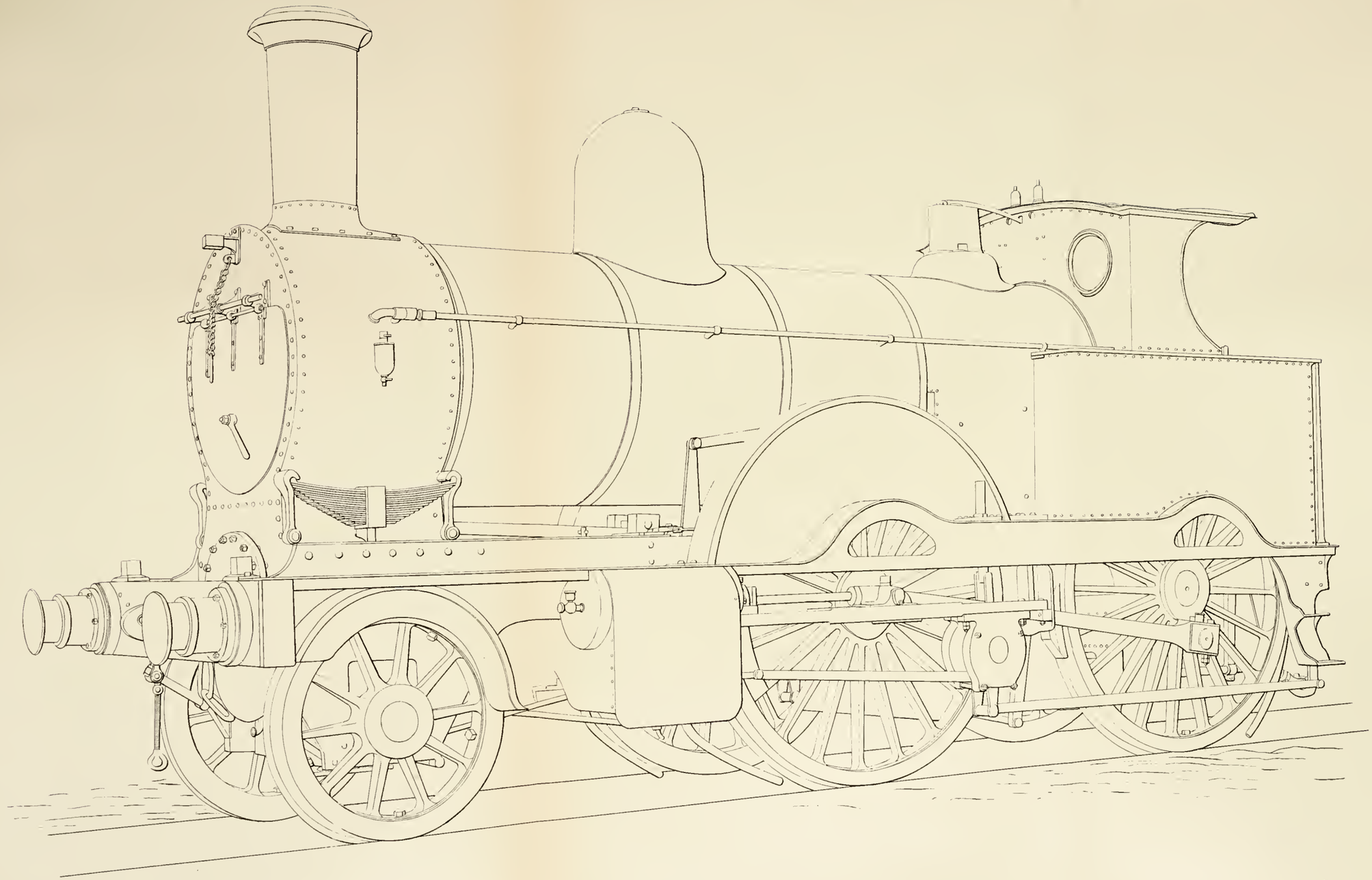
THE RAILWAY PRINTING & PUBLISHING COMPANY, 12, CRANE COURT, FLEET STREET E.C.

WEBB'S
LOCOM

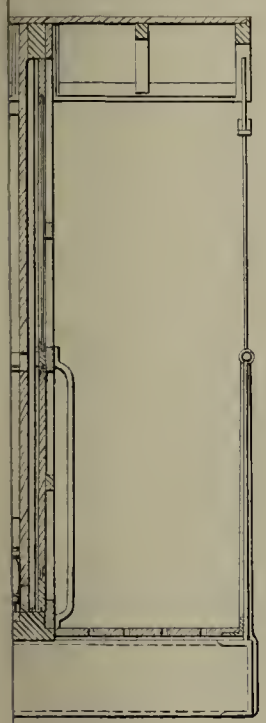
PLATE CXL



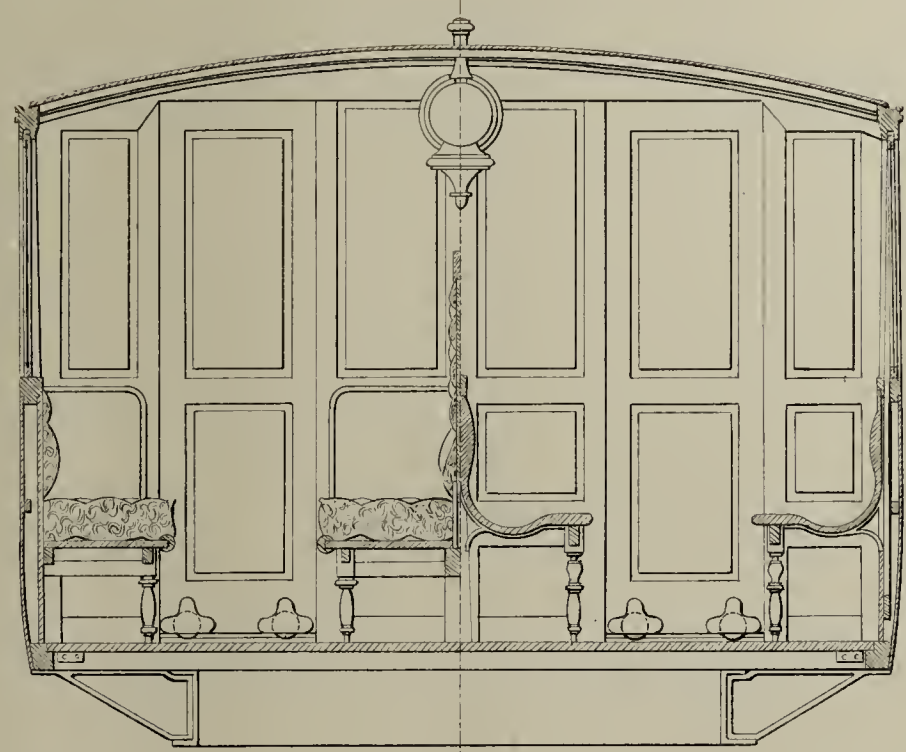
WEBB'S 3-CYLINDER COMPOUND
LOCOMOTIVE "EXPERIMENT"



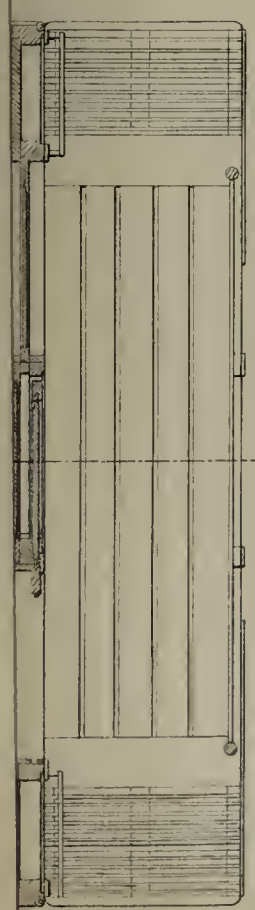
THE RAILWAY PRINTING & PUBLISHING COMPANY 12, CRANE COURT, FLEET STREET E.C



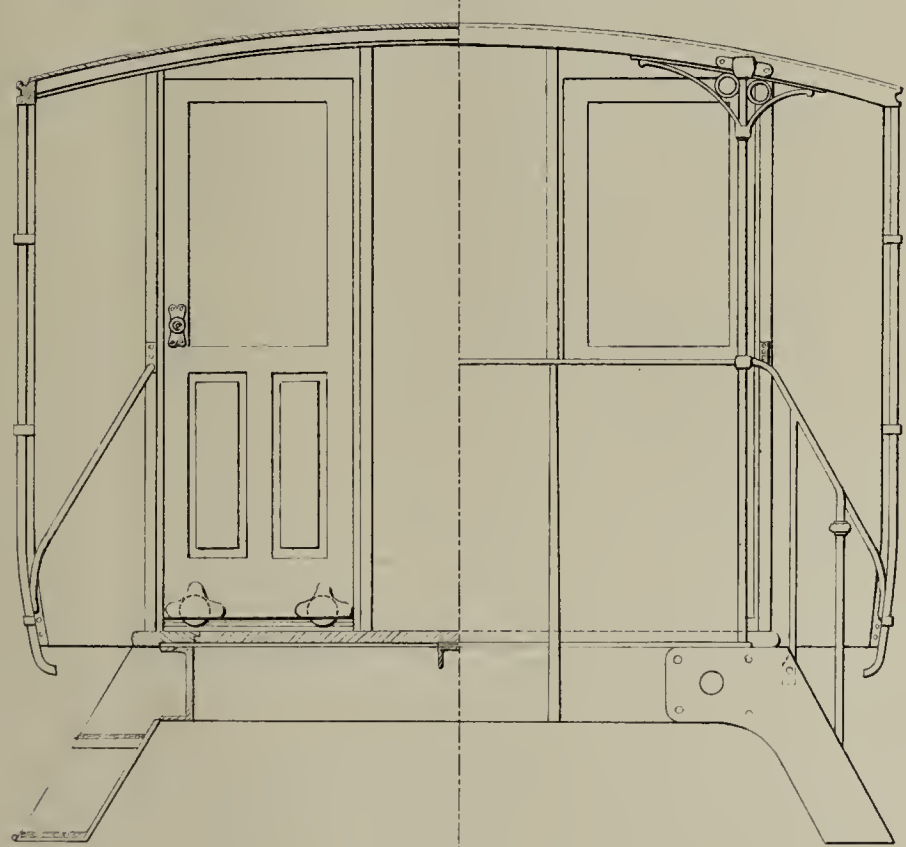
Section through 1st. Class



Section through 3rd. Class



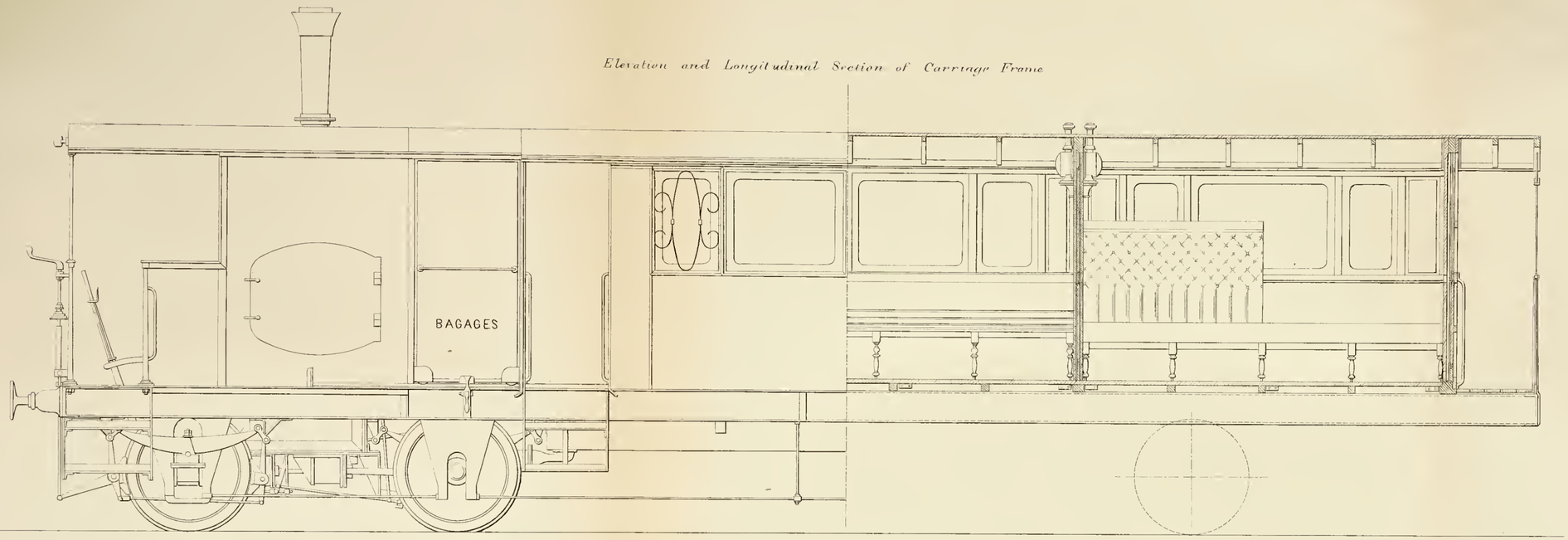
Section through Platform at End



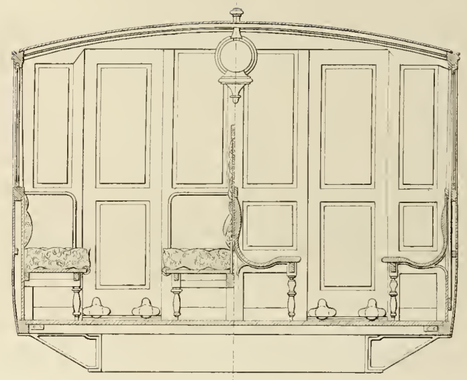
End View

THE RAILWAY ENGINEER.

Elevation and Longitudinal Section of Carriage Frame

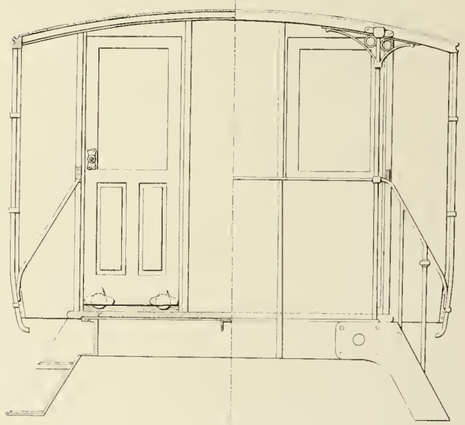


Section through 1st. Class



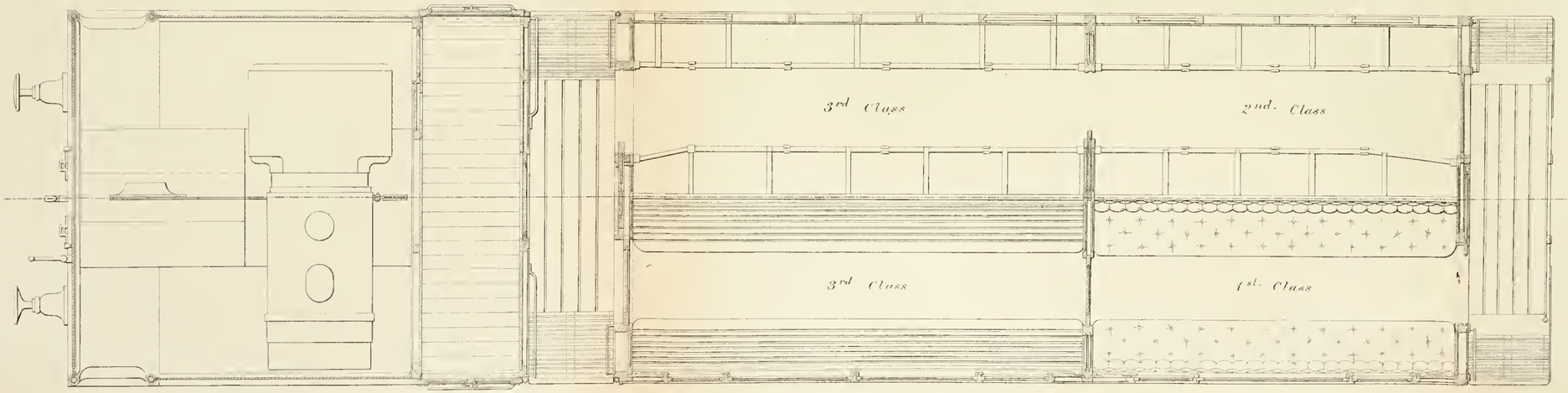
Section through 3rd. Class

Section through Platform at End



End View

Plan



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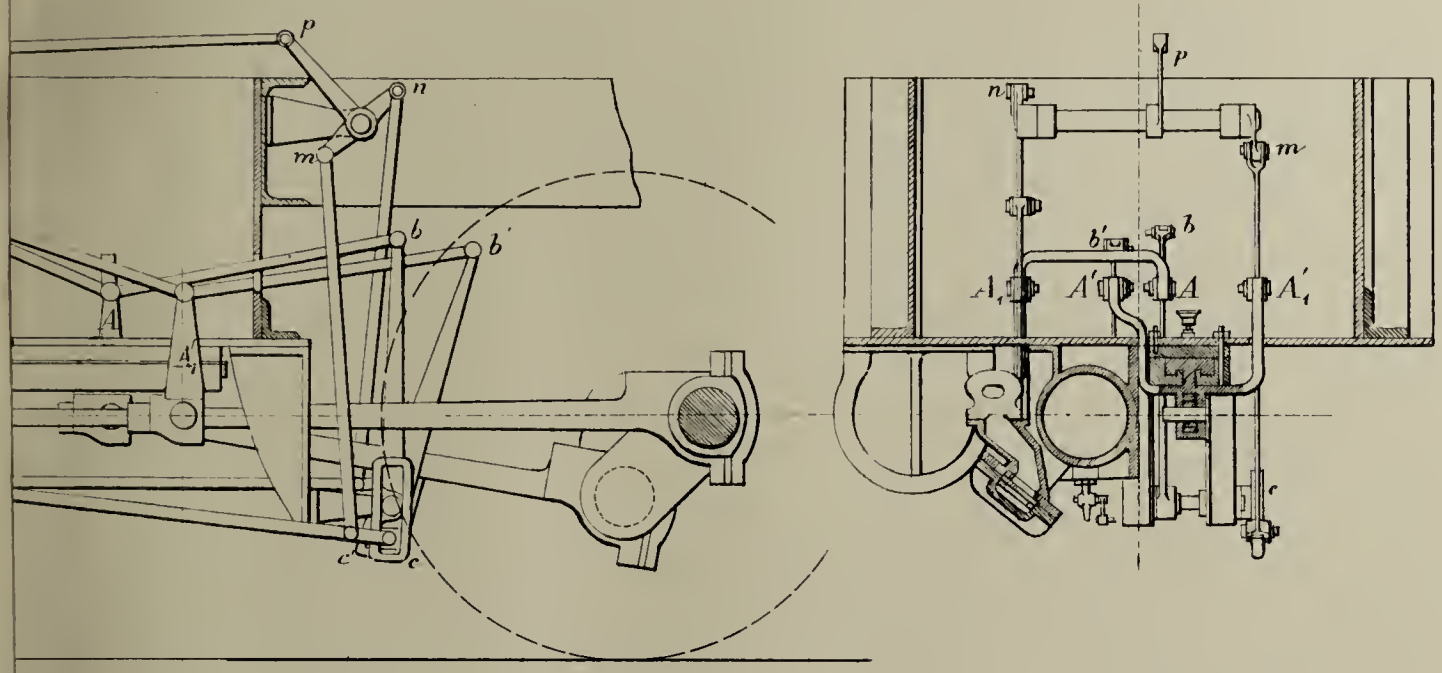
4. Slide Motion



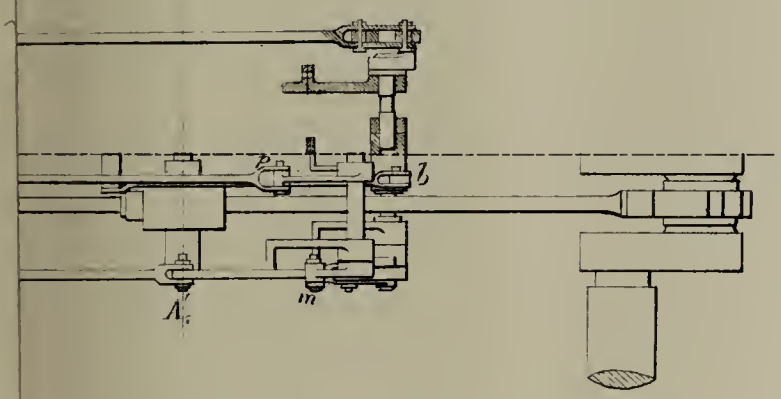


Fig. 3. Driving Axle

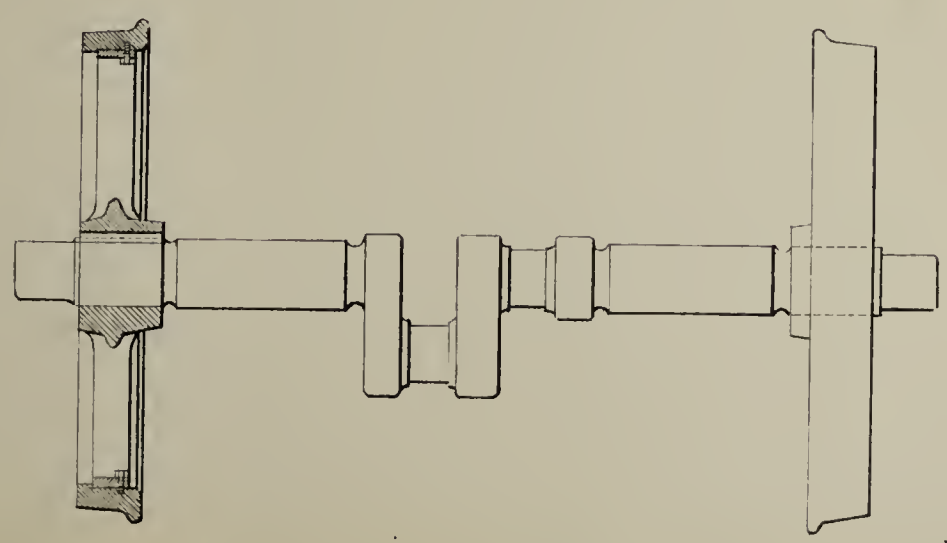


Fig. 1. Axle Box and Suspension of Rear Axle

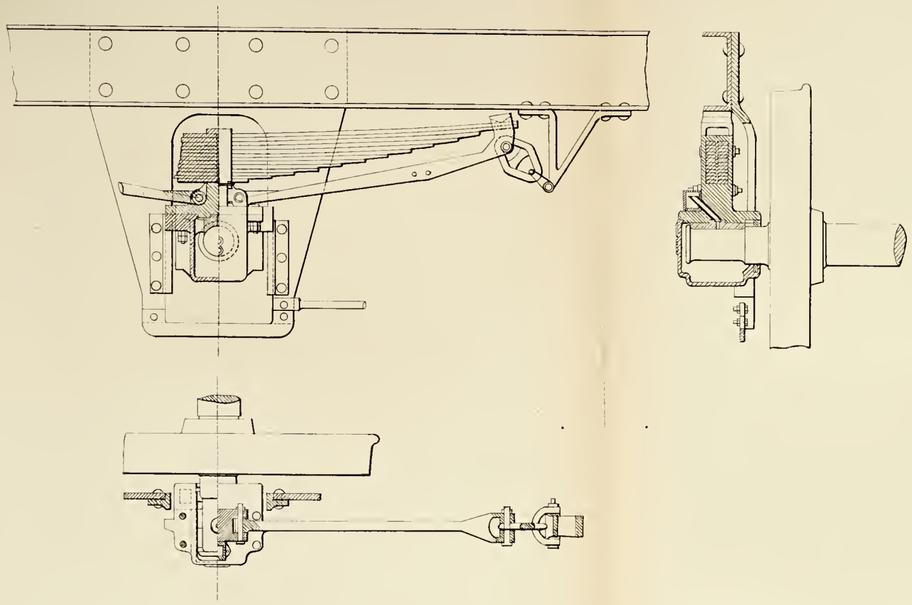
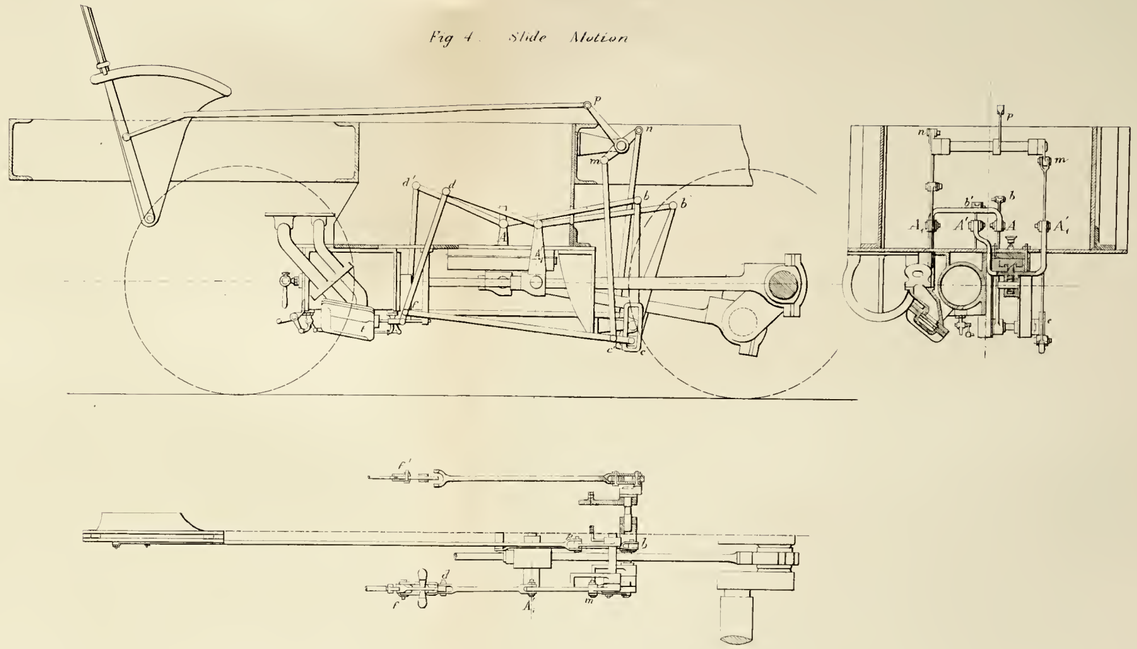
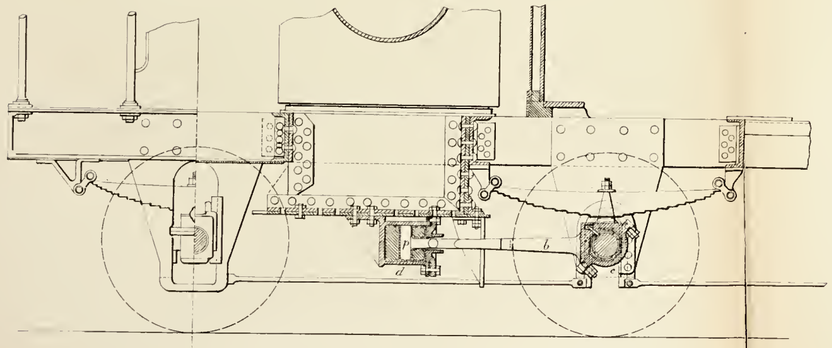


Fig 4 Slide Motion



Longitudinal Section through one India rubber Cylinder

Fig. 2.
Suspension of Engine at Forward End of Frame



Section through Driving Axle

Section through India-rubber Cylinder

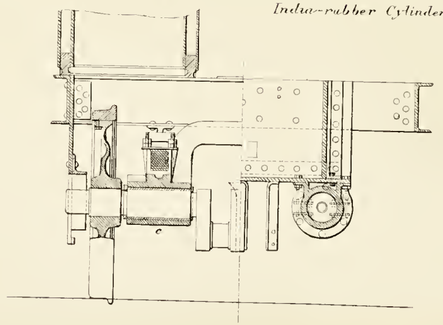
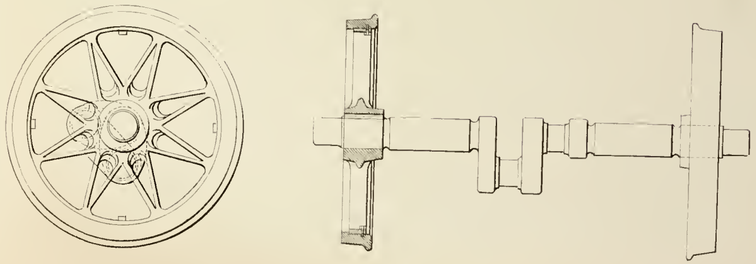
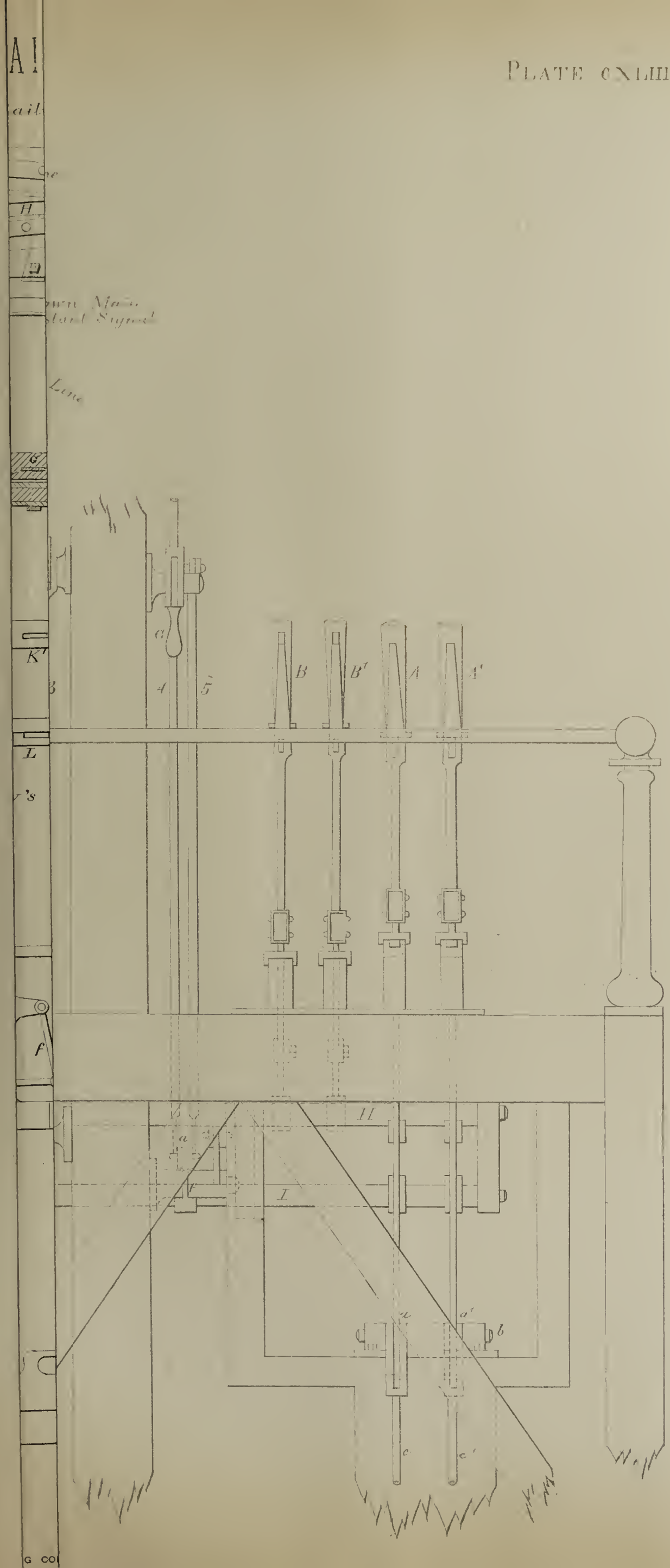


Fig 3 Driving Axle



THE RAILWAY PRINTING & PUBLISHING COMPANY, 12, CRANE COURT, FLEET STREET, E.C.

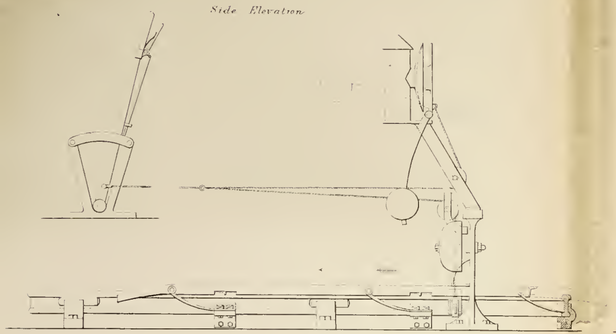
PLATE CXLIII



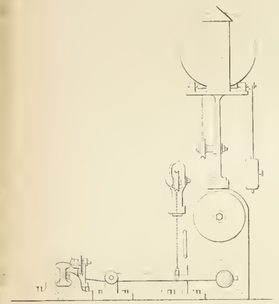
THE RAILWAY ENGINEER.

Sullivan's Electric Fog Signal

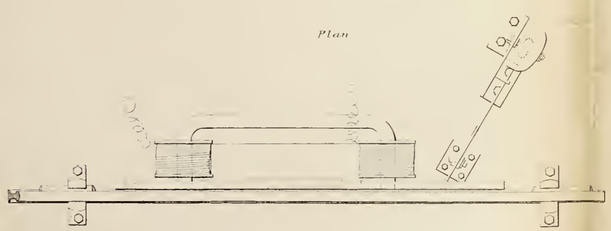
Side Elevation



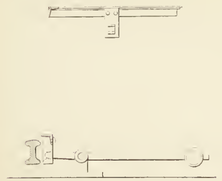
End Elevation



Plan



Details



Redfern's Railway Frog

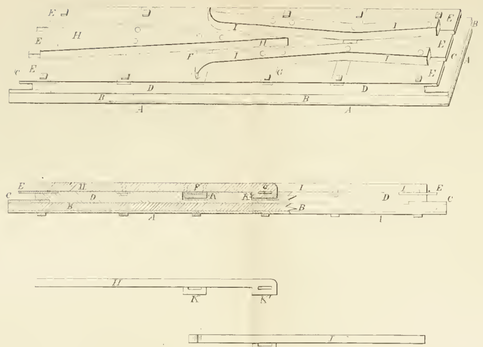


Fig. 191 Gregory's Invention of 1843

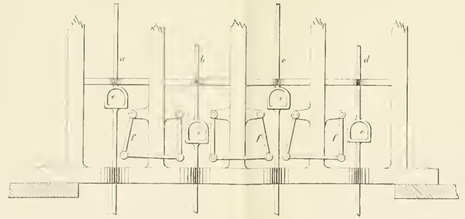


Fig. 192 Atkinson's Invention of 1852

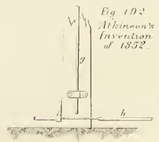


Fig. 193

Fig. 190

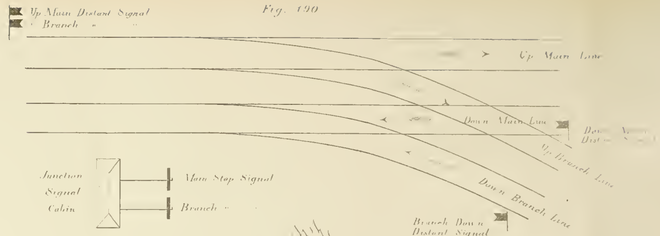
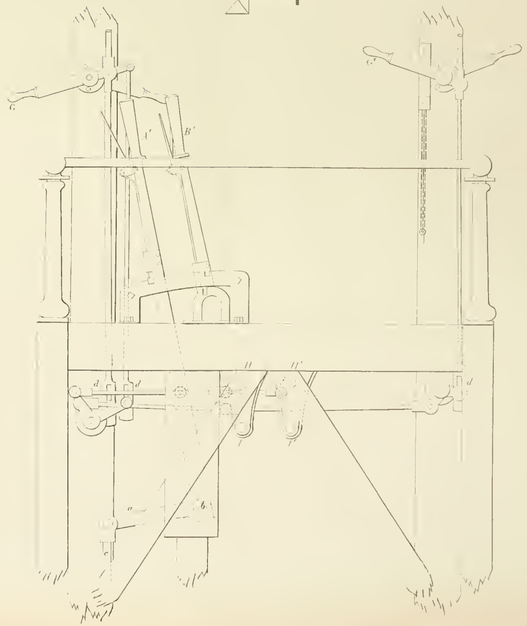
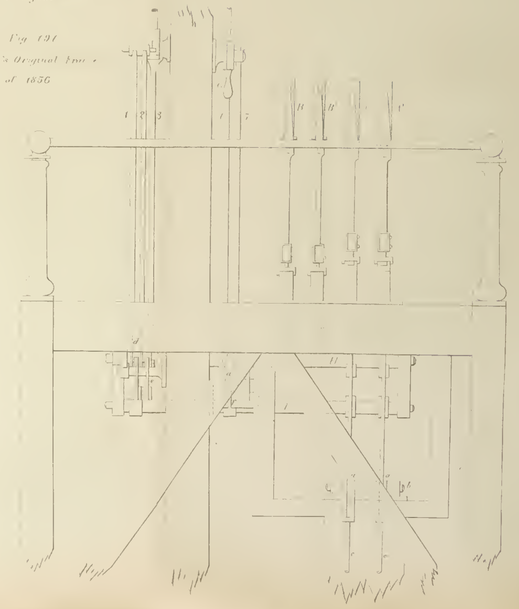


Fig. 194 Saxby's Original Frame of 1856

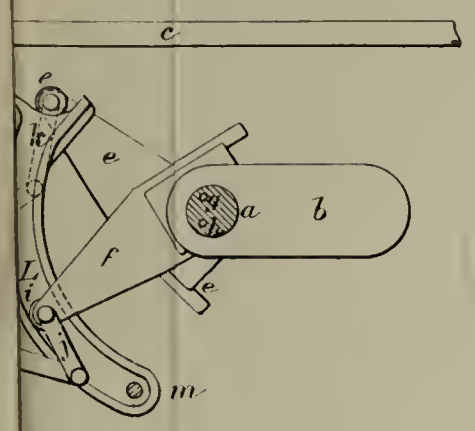


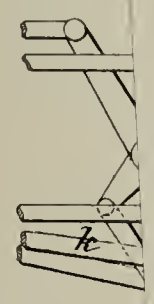


THE RAILWAY PRINTING & PUBLISHING COMPANY 12, CRANE COURT FLEET STREET, E.C.

VALV

Gray's Gear





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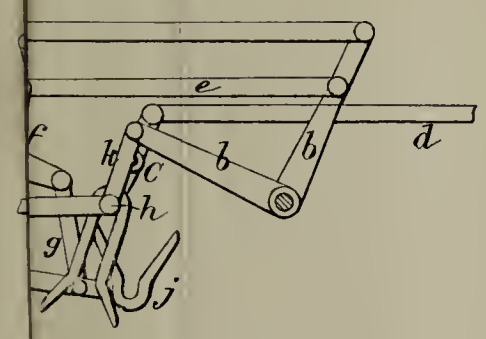
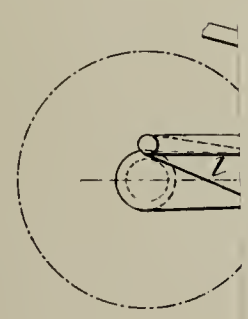




Link Motion.

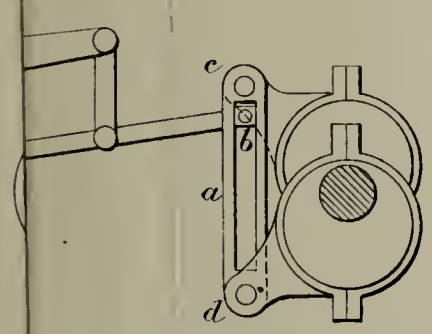
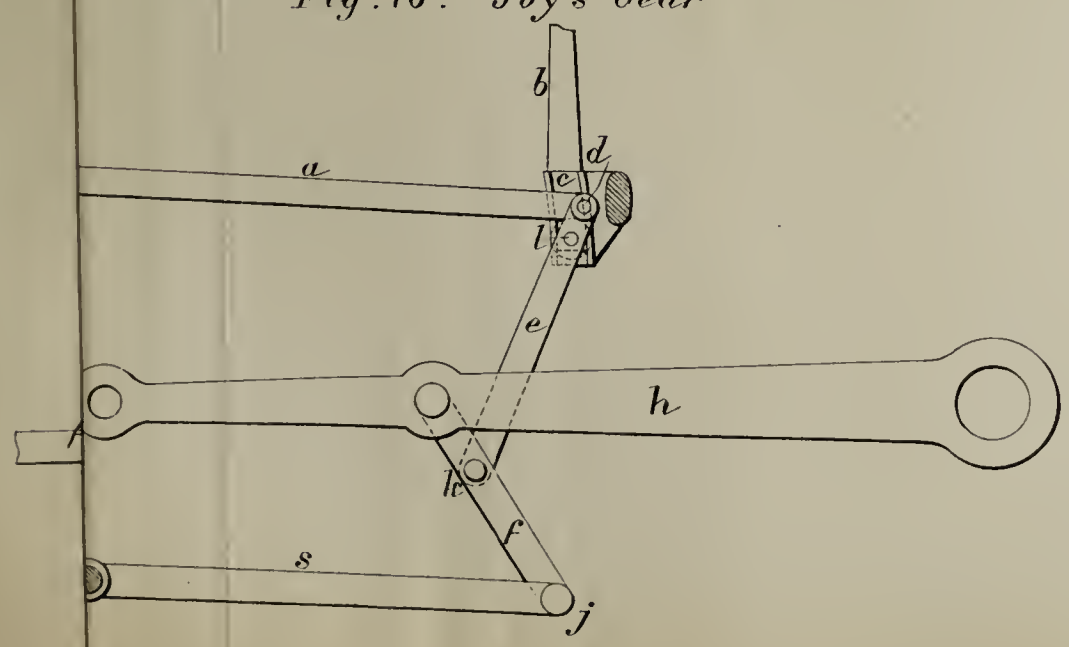


Fig. 16. Joy's Gear



THE RAILWAY ENGINEER.

Fig. 1.

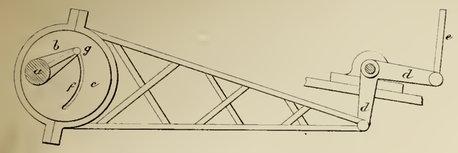


Fig. 2. Bury's Gear. 1830.

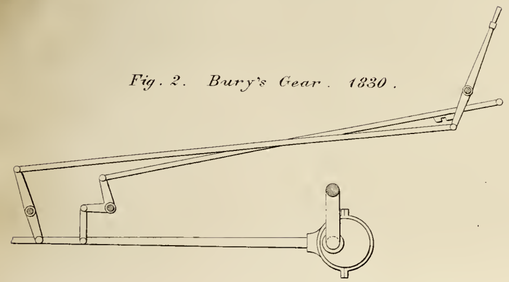


Fig. 3. Carmichael's Gear.

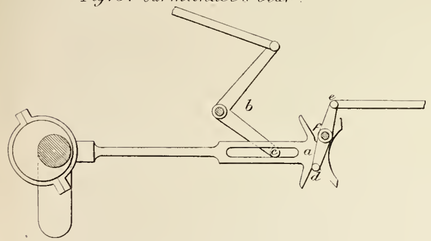


Fig. 4.

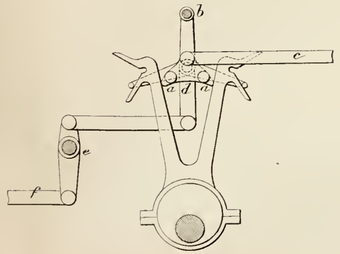


Fig. 5. Hawthorn's Gear of 1837.

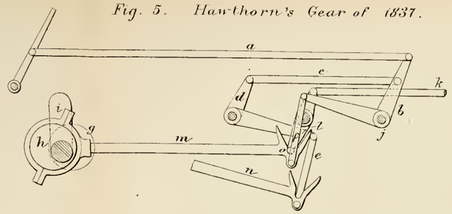


Fig. 6.

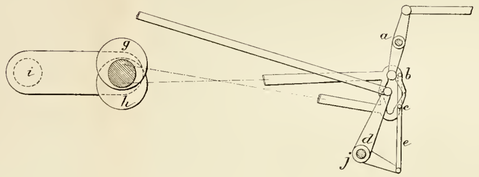


Fig. 7. Melling's Gear. 1830.

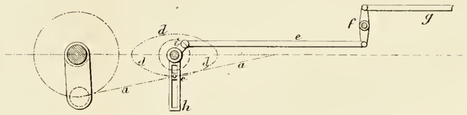


Fig 8. Hawthorn's Gear of 1838.

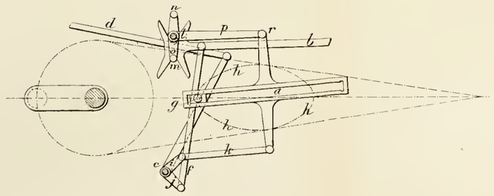


Fig. 9. Gray's Gear

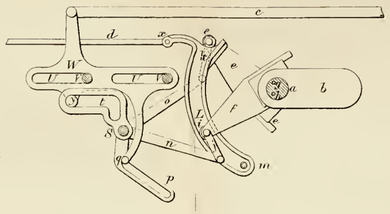


Fig. 10.

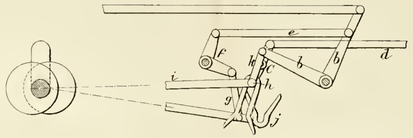


Fig. 11. First Link Motion.

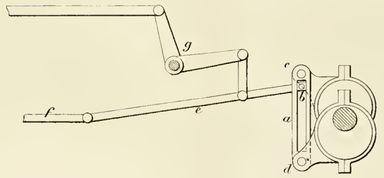


Fig. 12. Howe. 1843.

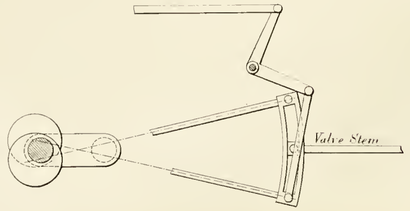


Fig. 13.

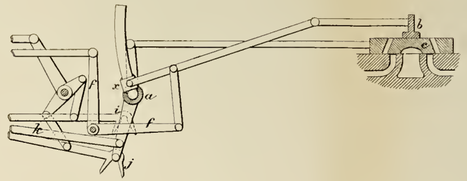


Fig. 14. Walschaert Gear

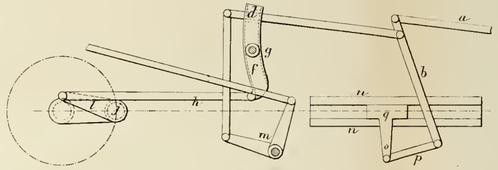


Fig. 15. Allen Gear

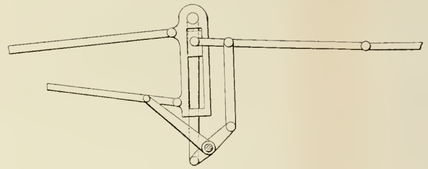
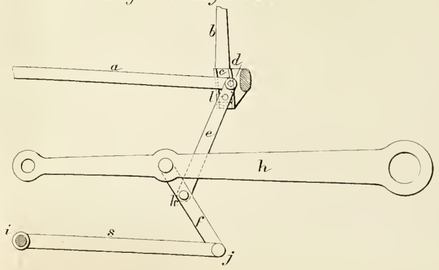
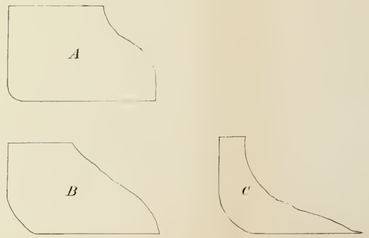


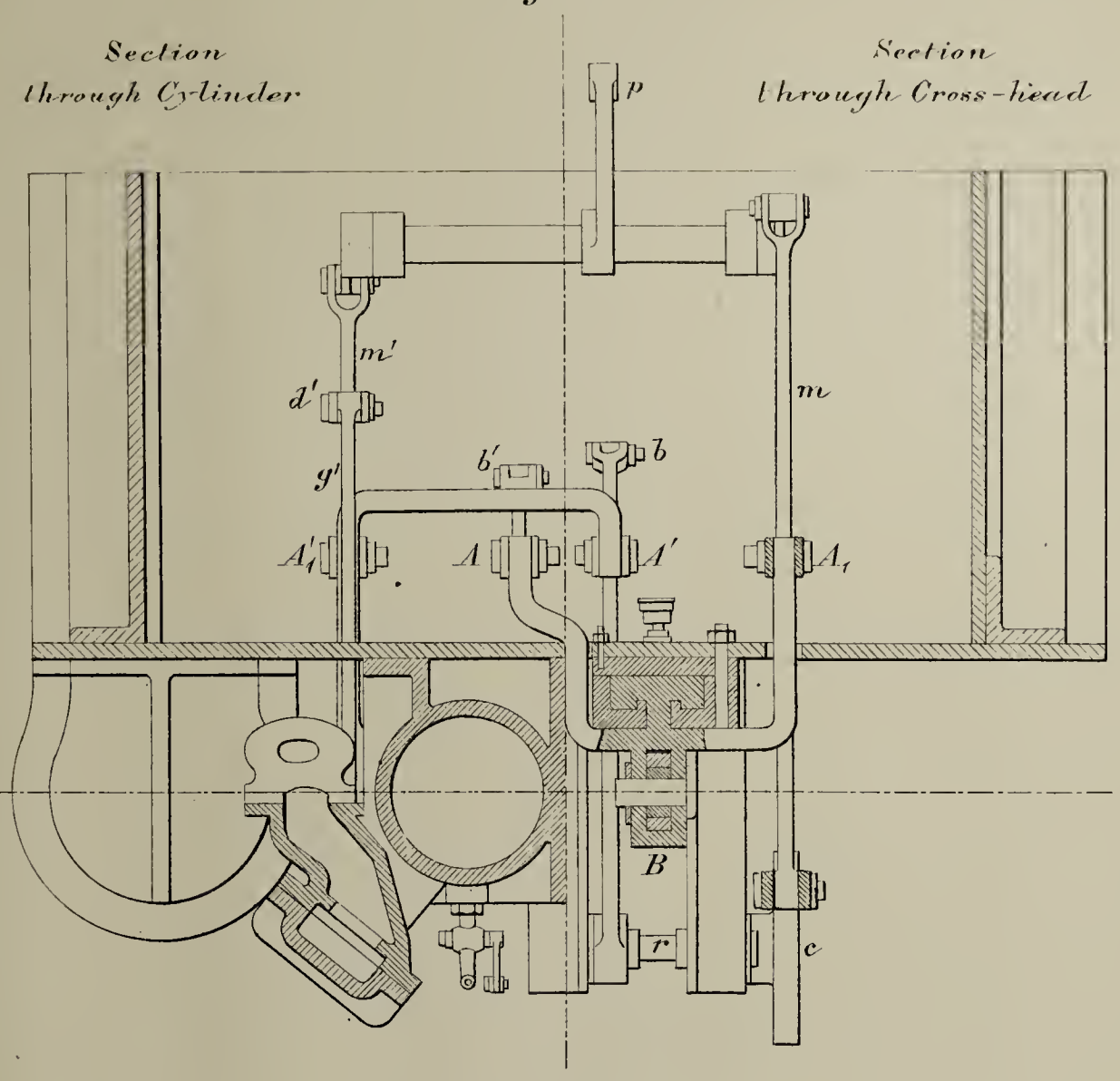
Fig. 16. Joy's Gear





THE RAILWAY PRINTING & PUBLISHING COMPANY, 12, CRANE COURT, FLEET STREET E.C.

Fig. 2


Section
through Cylinder
Section
through Cross-head
p
m'
d'
g'
b'
b
m
A'1
A
A'
A1
B
r
c

LIGHT RAILWAYS

BELPAIRE'S STEAM CARRIAGE

Slide Motion

Fig. 1.
Sectional Elevation

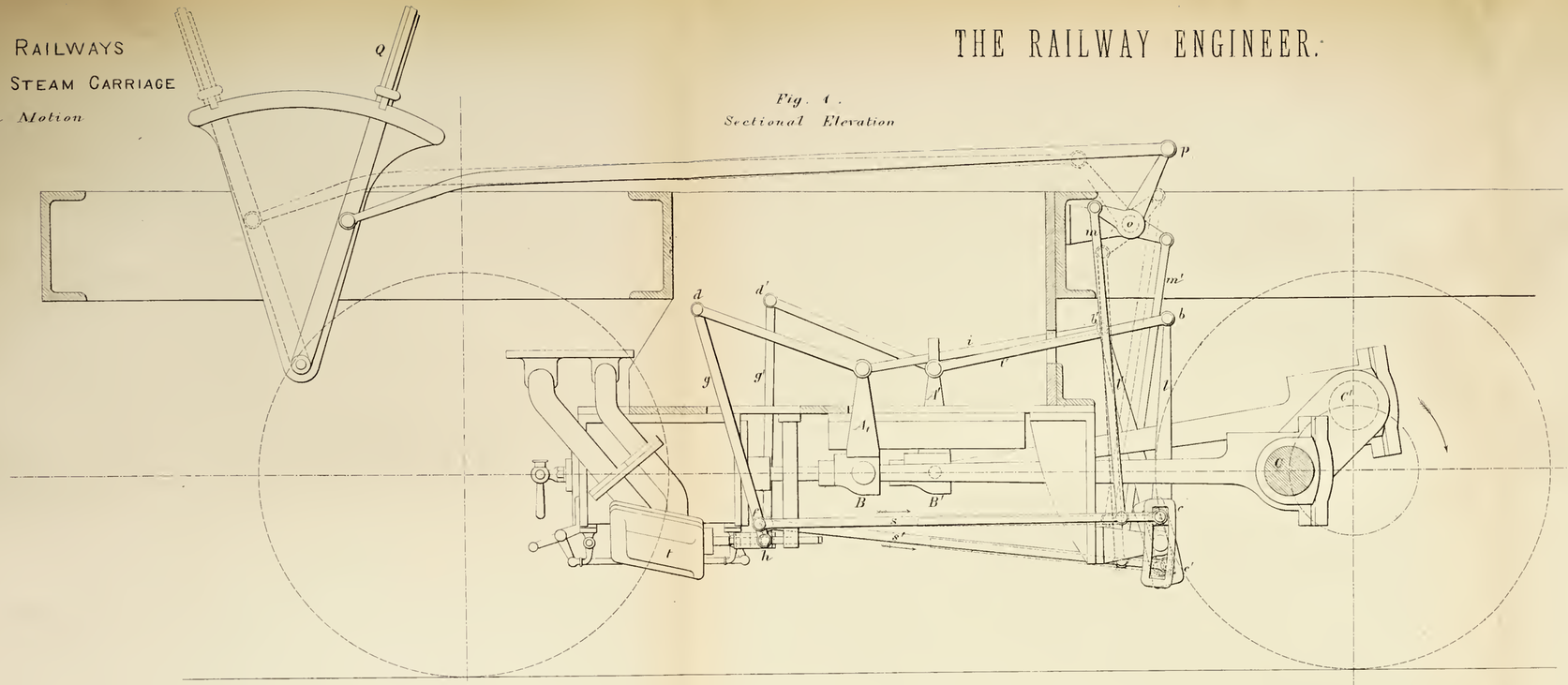


Fig. 2

Section through Cylinder

Section through Cross-head

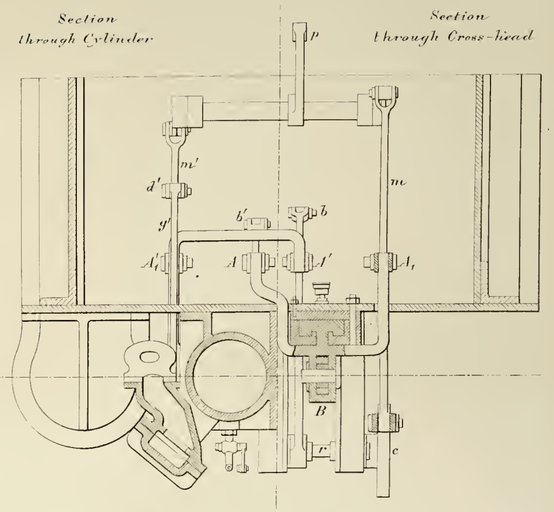
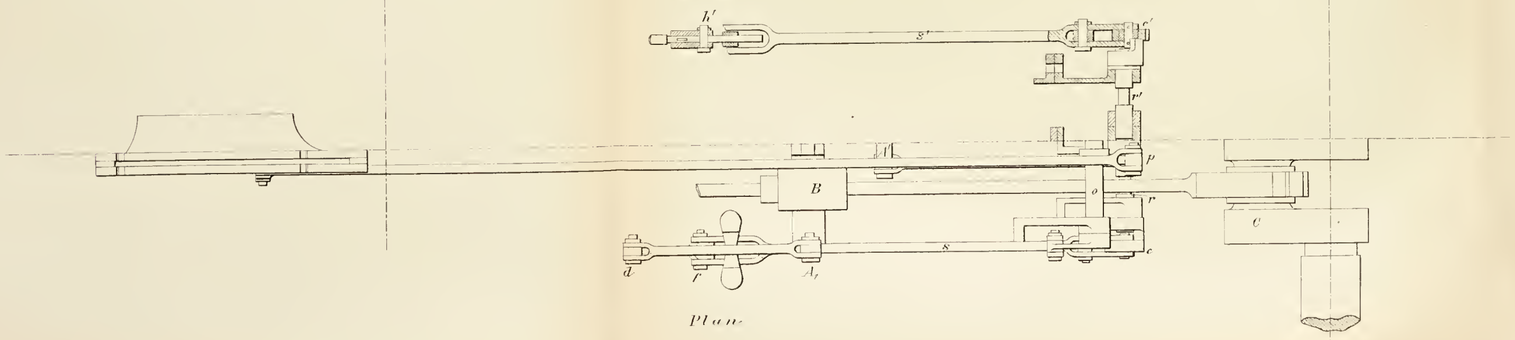
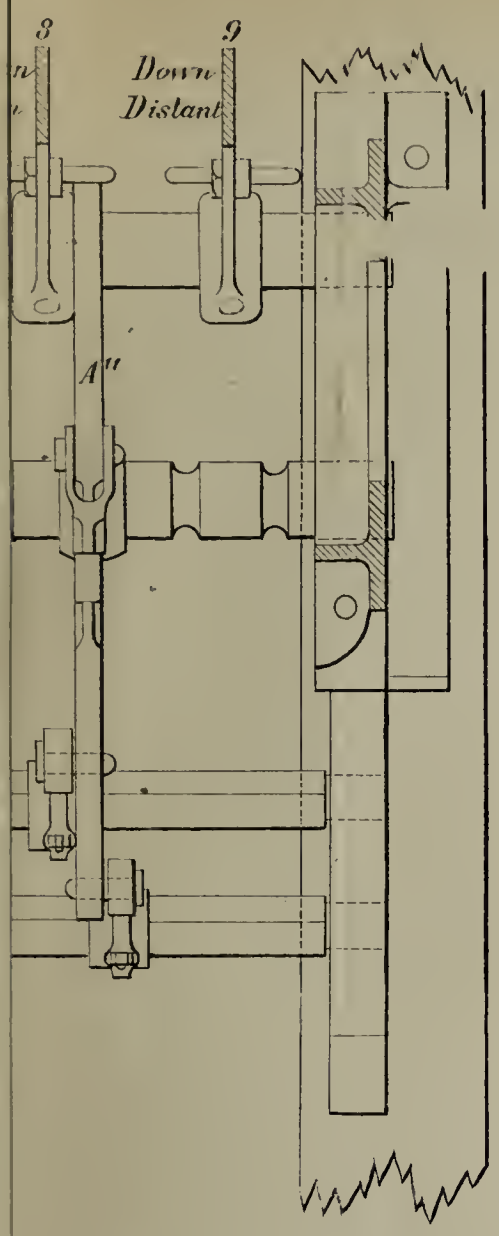


Fig. 3.
Sectional Plan



Plan.

THE RAILWAY PRINTING & PUBLISHING COMPANY 12, CRANE COURT, FLEET STREET, E.C.



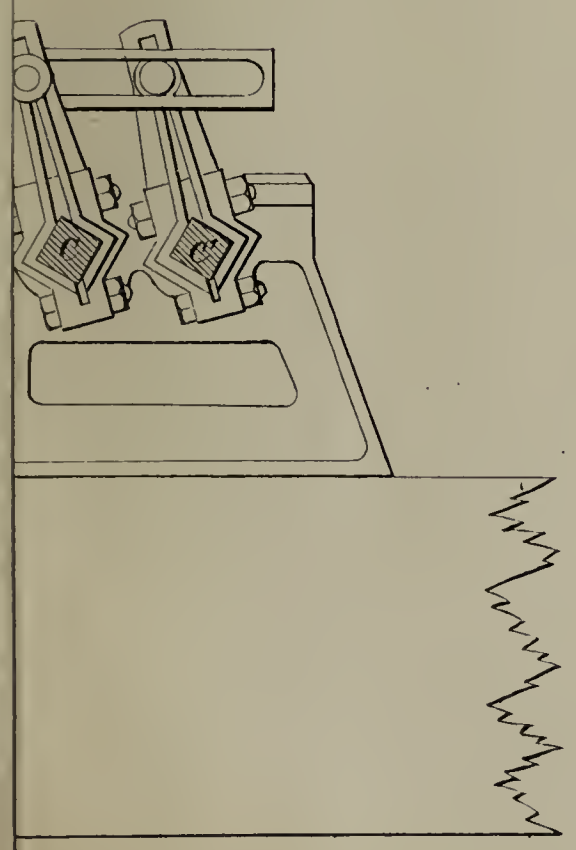
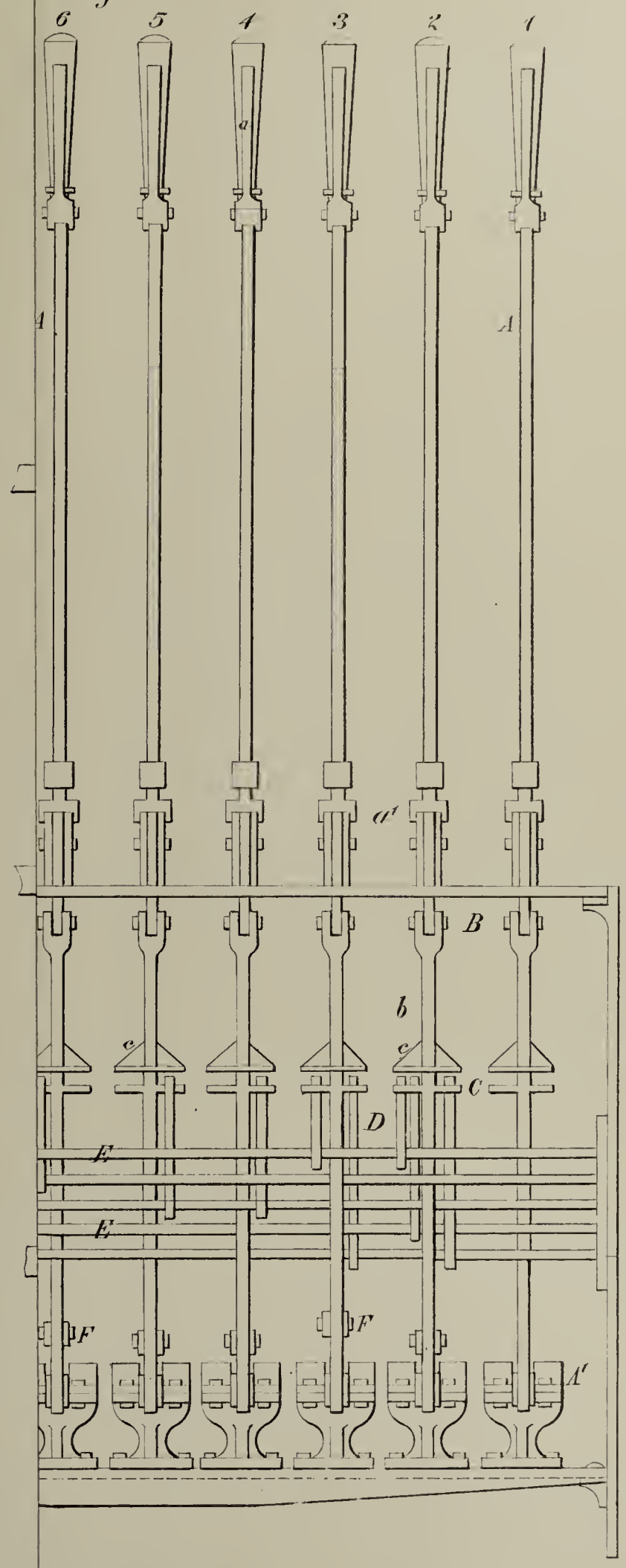


Fig. 213.



NG COMPANY, 12, CRANE COURT, FLEET STREET, E.C.

RAILWAY SIGNALLING INTERLOCKING

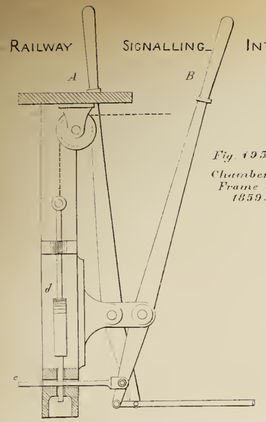


Fig. 195. Chamber's Frame of 1859.

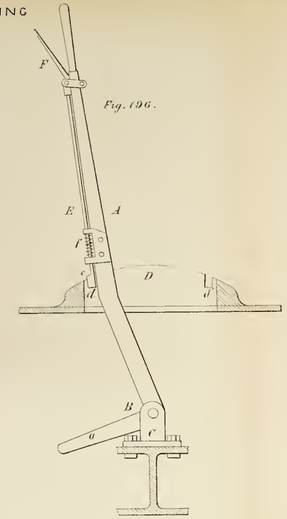
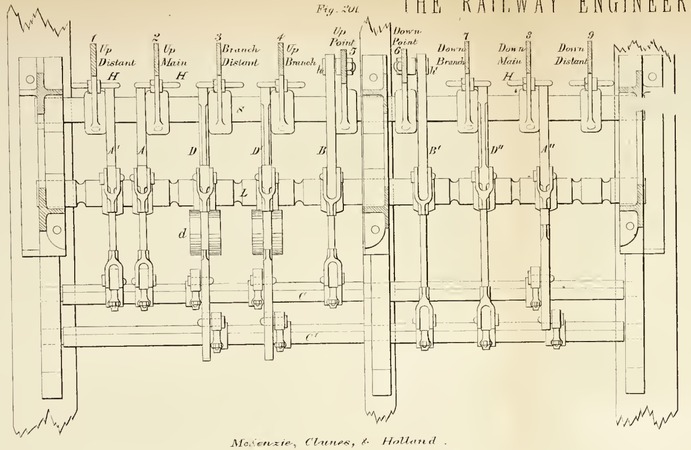


Fig. 196.

Fig. 201



Mackenzie, Clunes, & Holland.

Fig. 197.

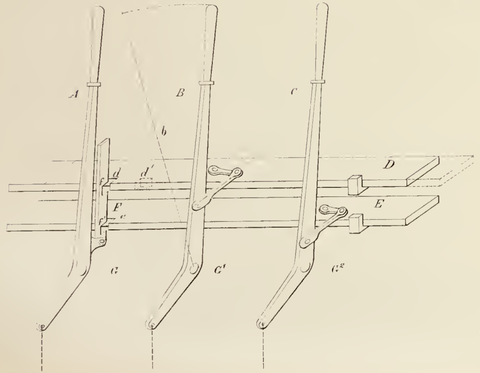


Fig. 199. Lane's Frame

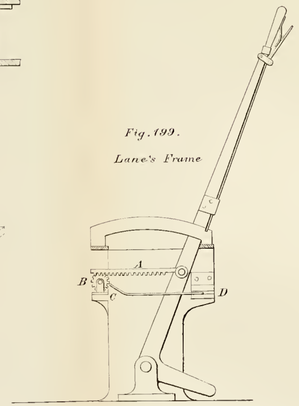


Fig. 200.

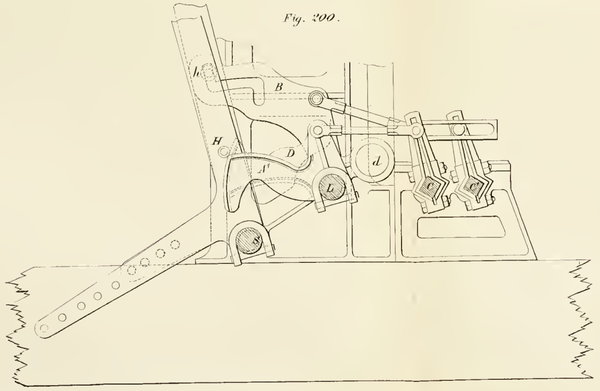
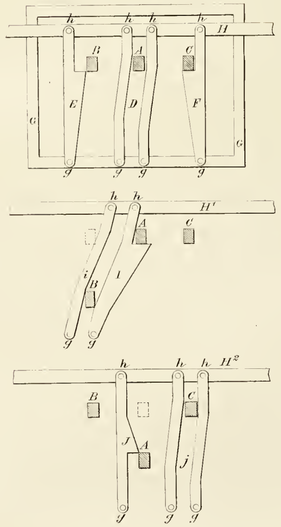


Fig. 198. Saxby. 1860.



Easterbrook. 1867.

Fig. 212

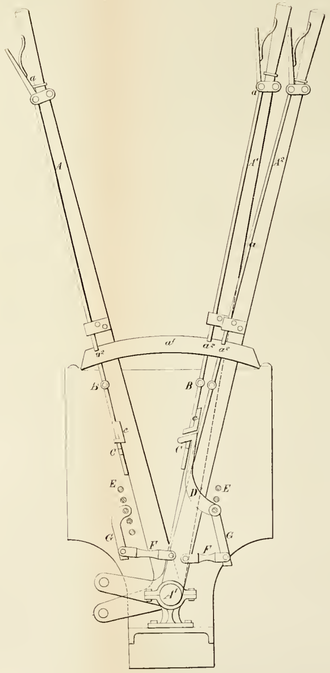
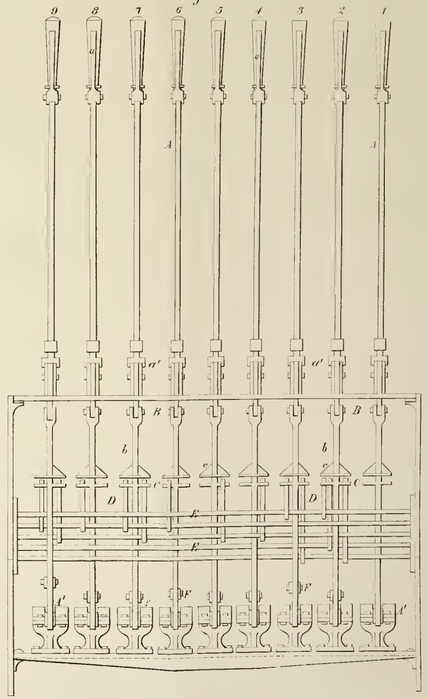


Fig. 213.



THE RAILWAY PRINTING & PUBLISHING COMPANY, 12, CRANE COURT, FLEET STREET, E.C.

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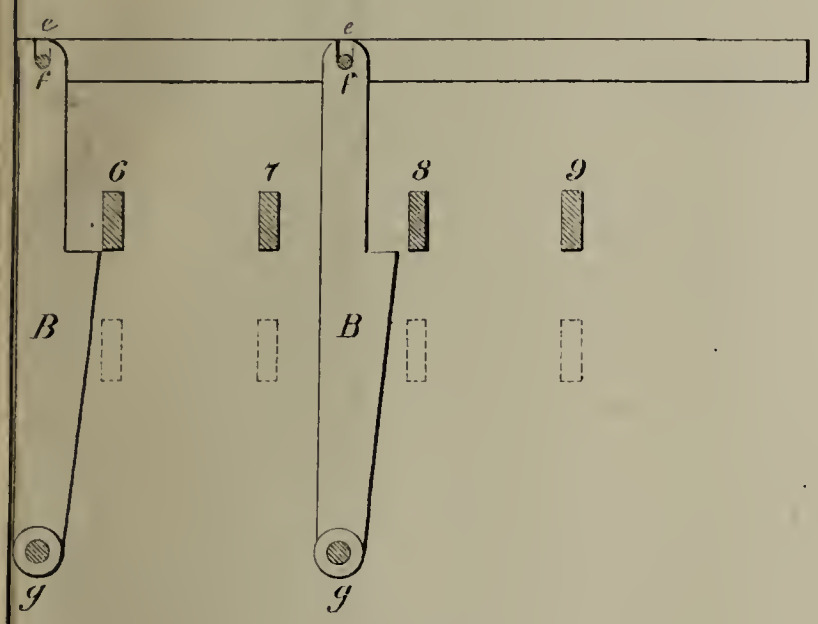

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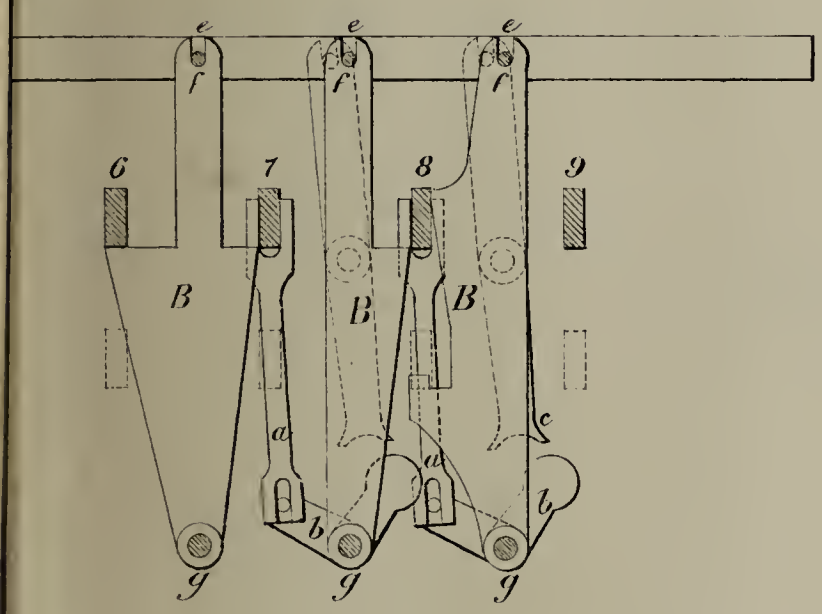

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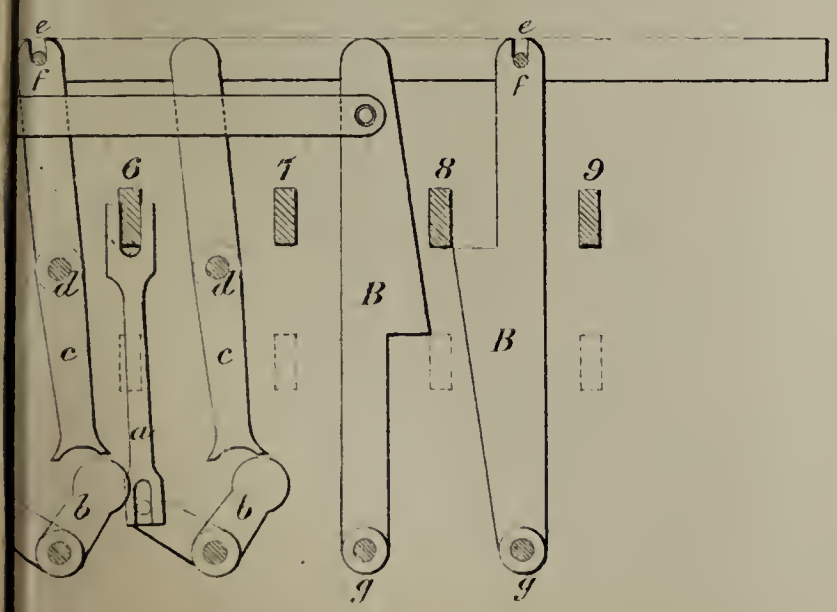

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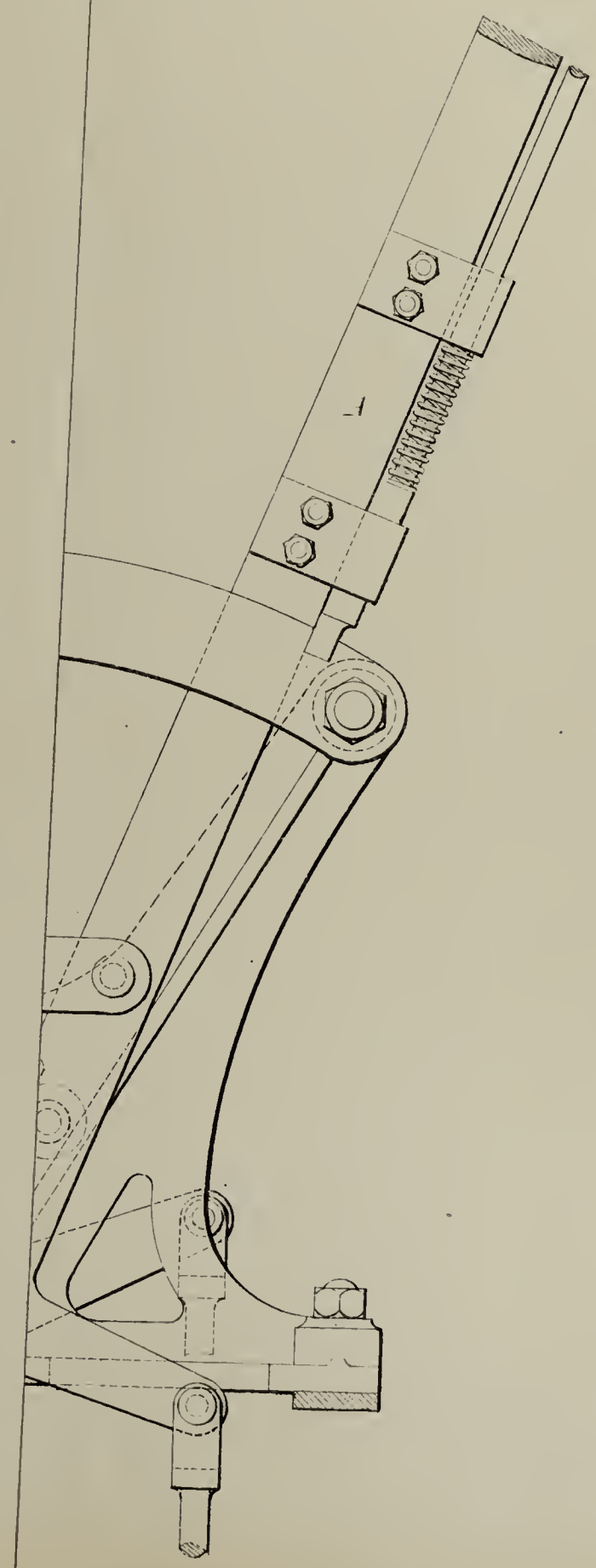


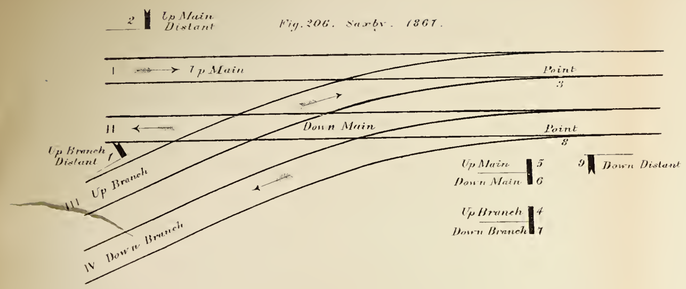


Fig. 206. Saxby. 1867.

Saxby. 1867.
Fig. 204. Fig. 205.

Saxby. 1867.
Fig. 202.

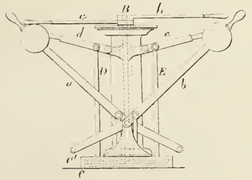


Fig. 203.

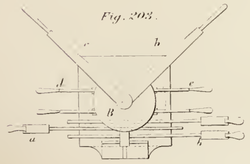
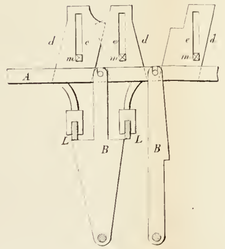


Fig. 211. Saxby. 1867.



Saxby 1867.

Fig. 207.

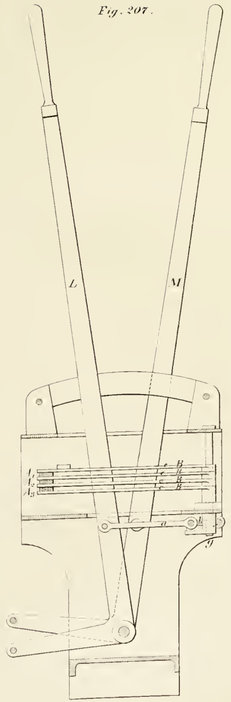


Fig. 208.

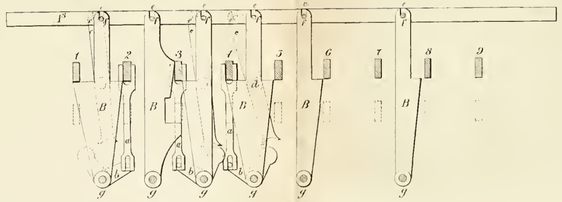


Fig. 209.

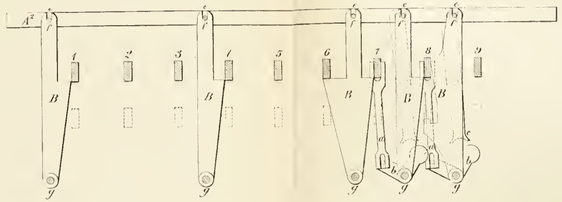


Fig. 210.

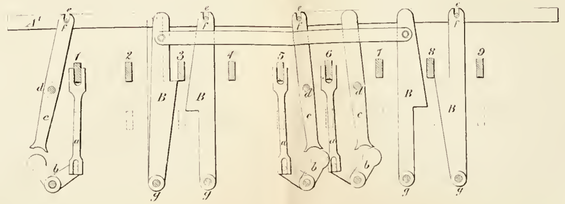


Fig. 213. Napier. 1869.

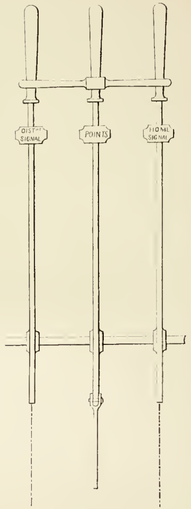
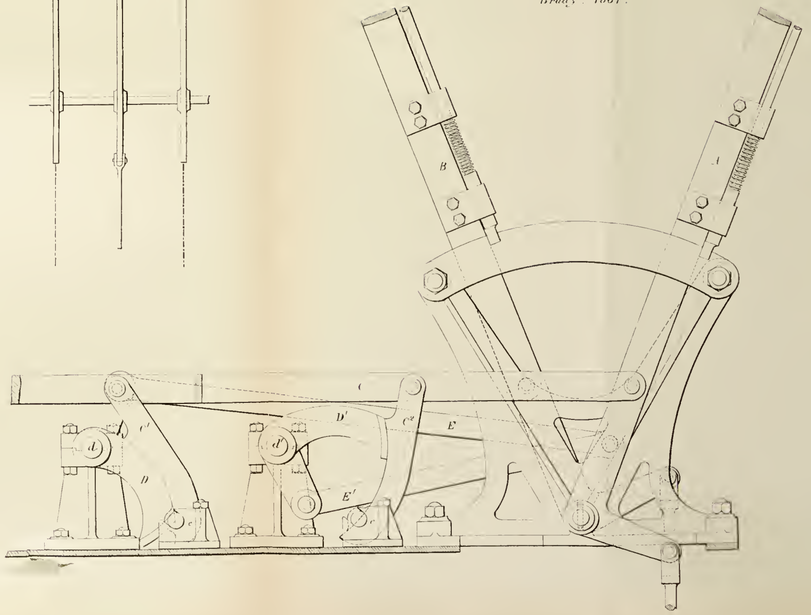
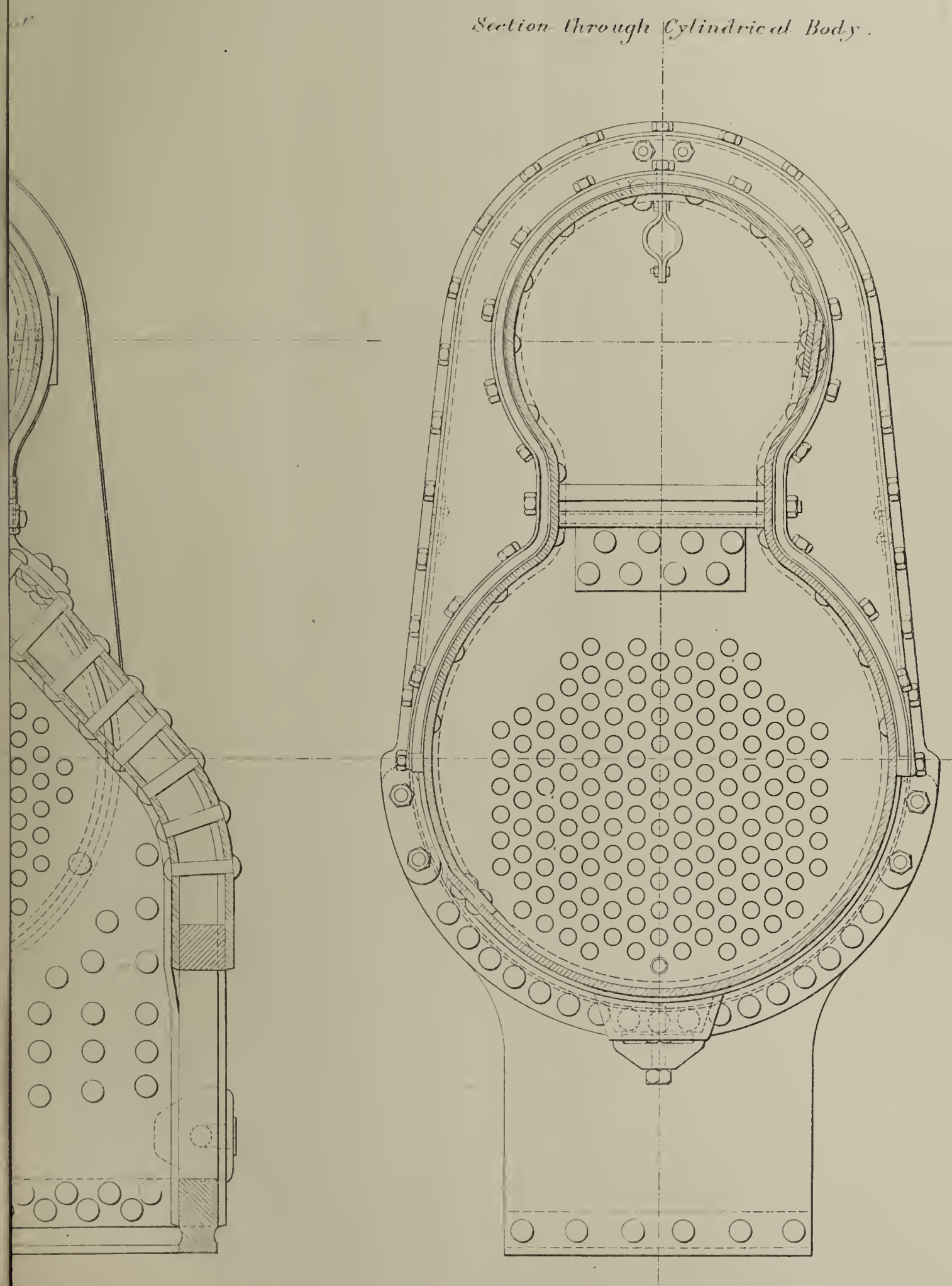


Fig. 214
Brady. 1867.



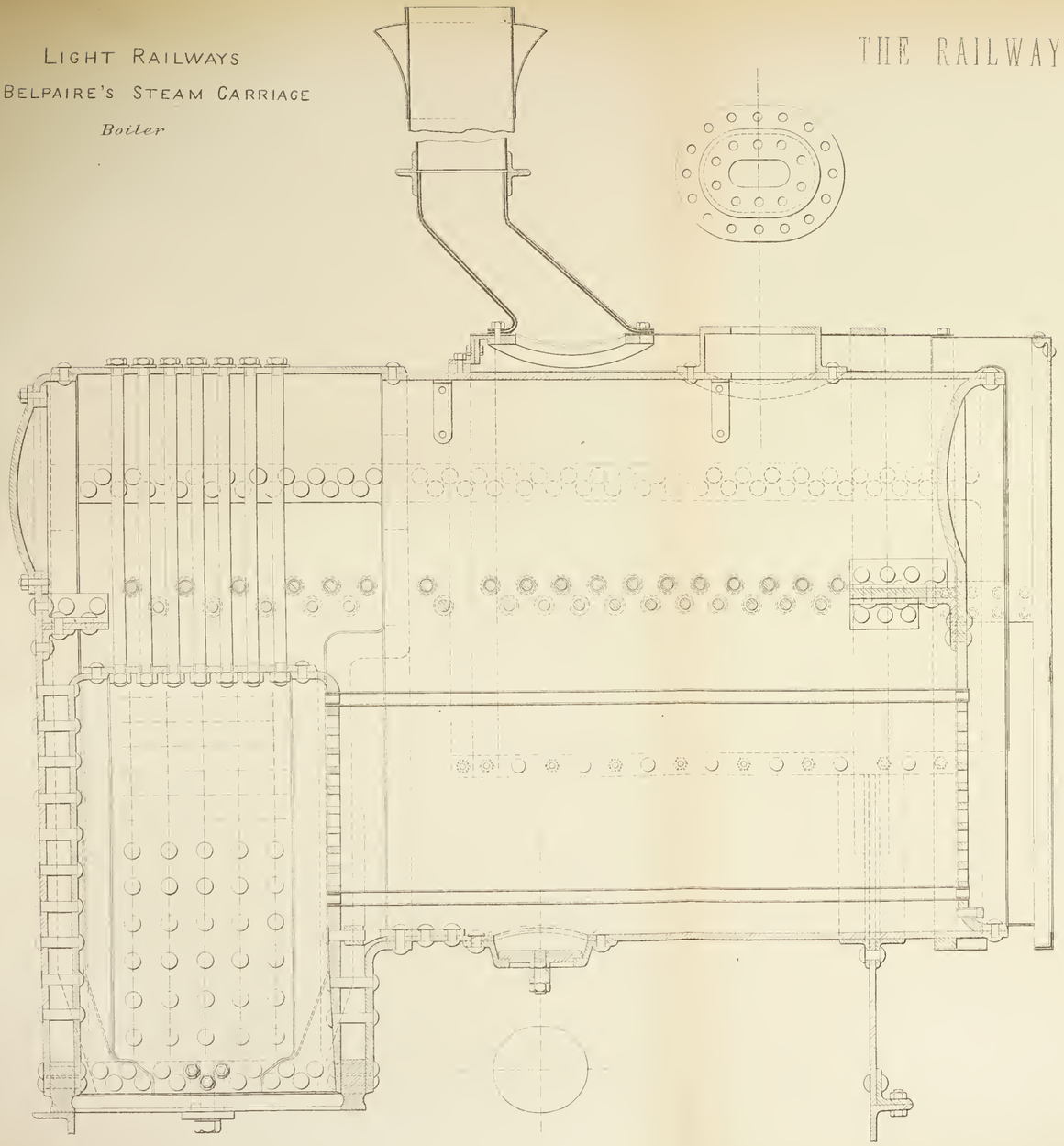
THE RAILWAY PRINTING & PUBLISHING COMPANY 17, CRANE COURT FLEET STREET E.C.


Section through Cylindrical Body.

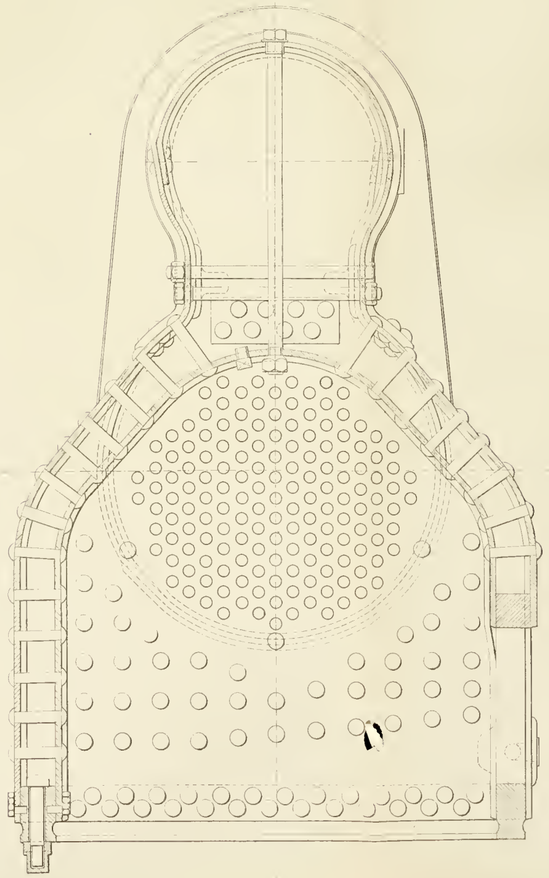
LIGHT RAILWAYS

BELPAIRE'S STEAM CARRIAGE

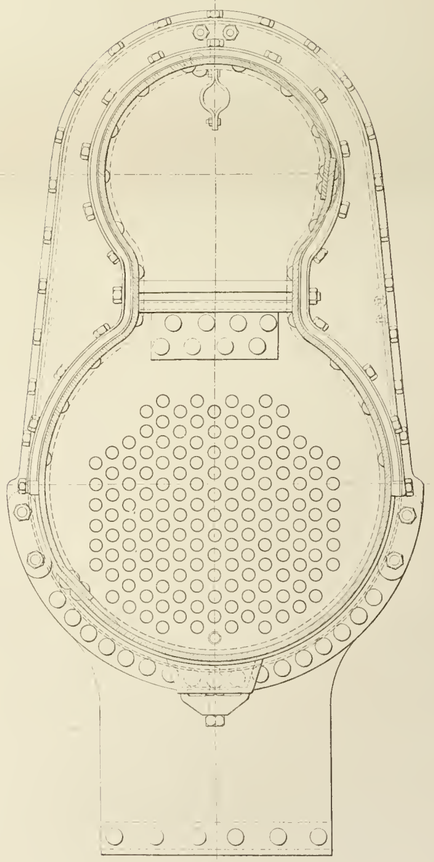
Boiler



Section through Centre of Fire-box



Section through Cylindrical Body



THE RAILWAY PRINTING & PUBLISHING COMPANY 12 CRANE COURT FLEET STREET

Section through Fire-box

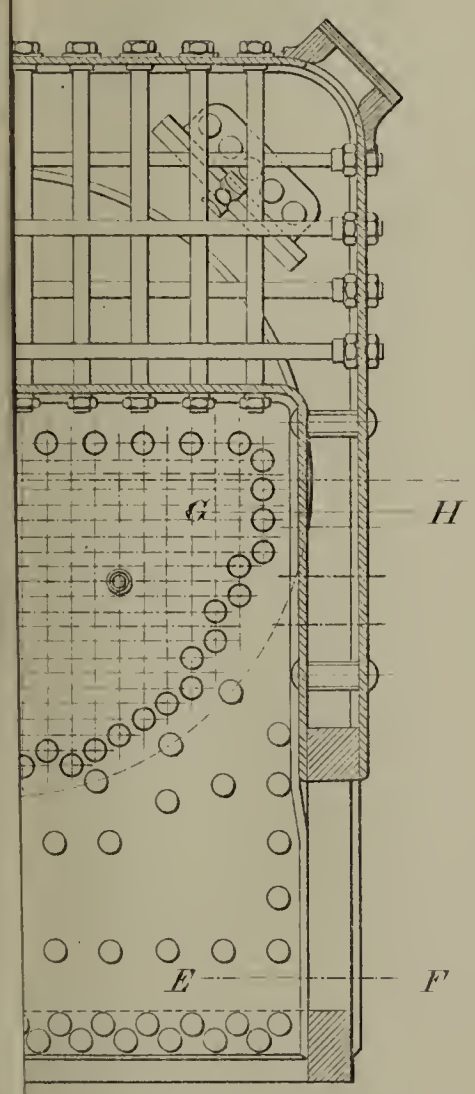
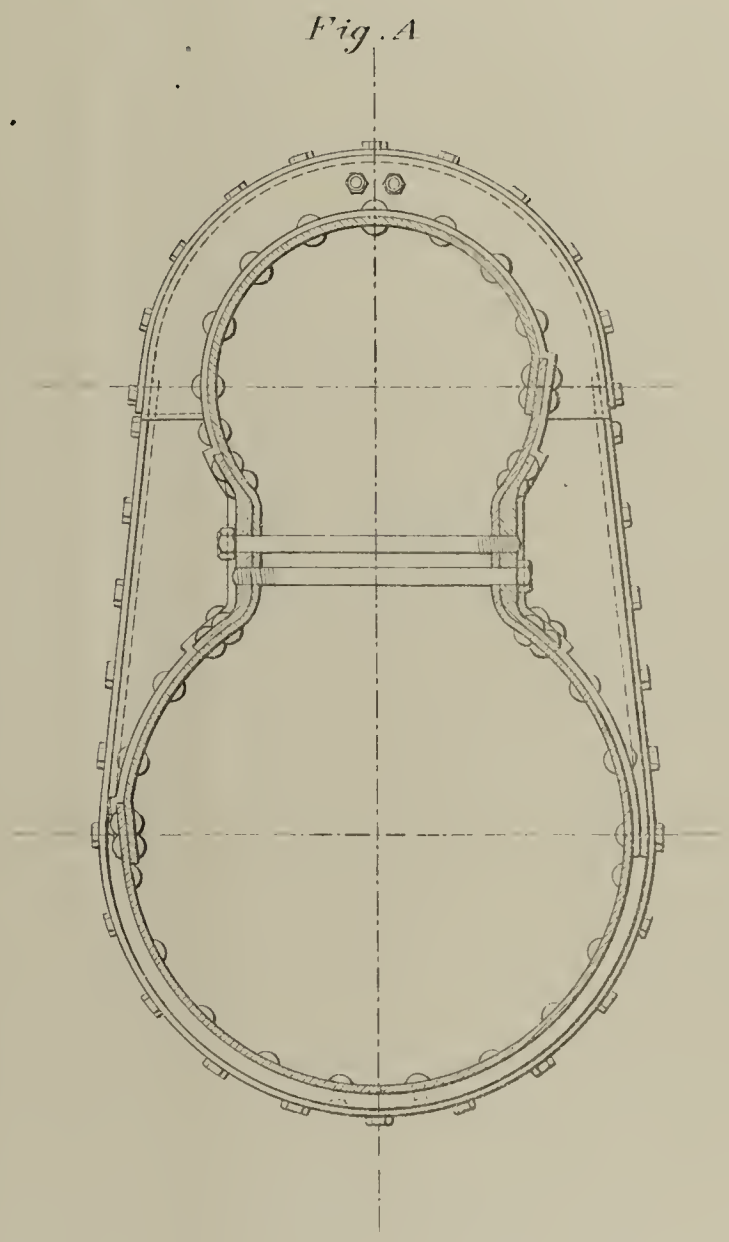
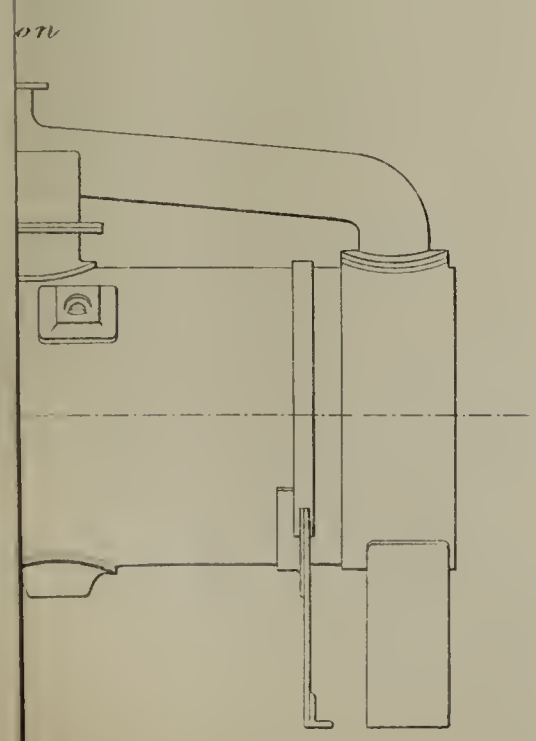
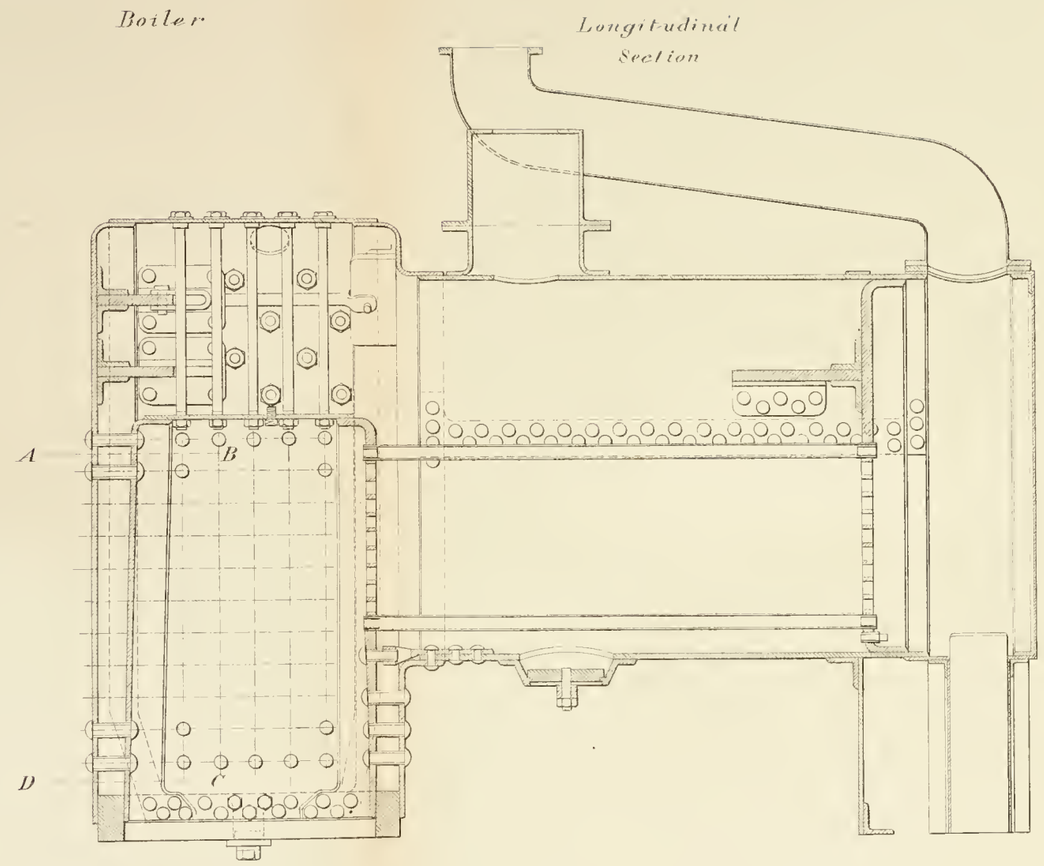


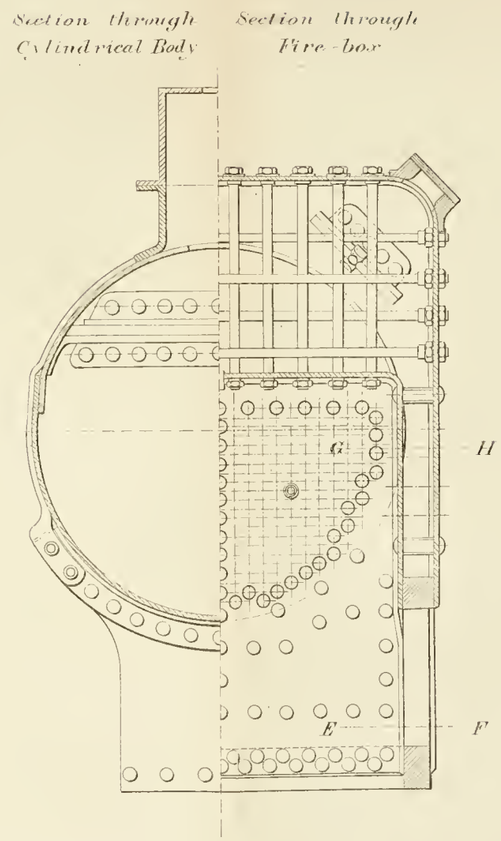
Fig. A

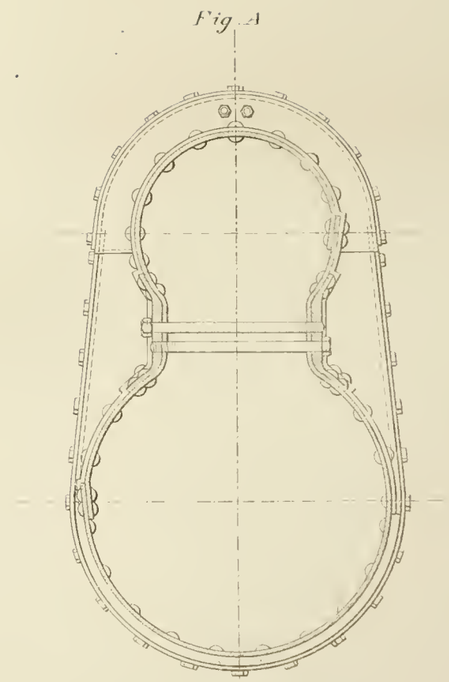


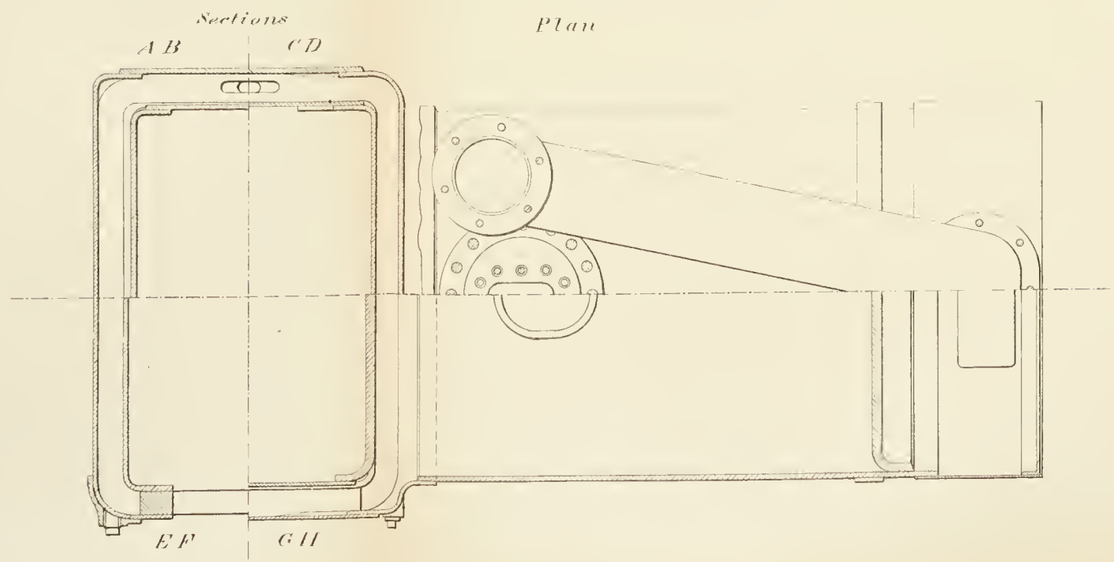


BELPAIRE'S STEAM CARRIAGE









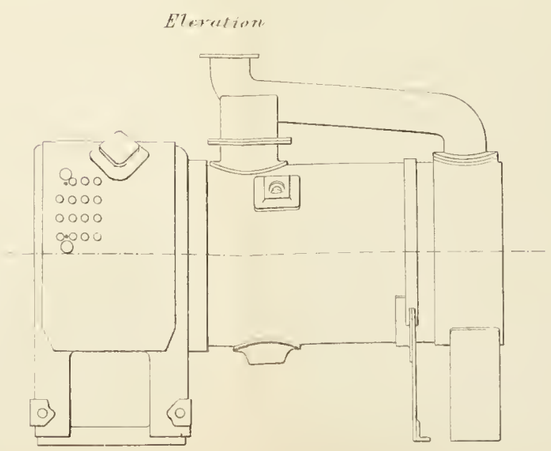


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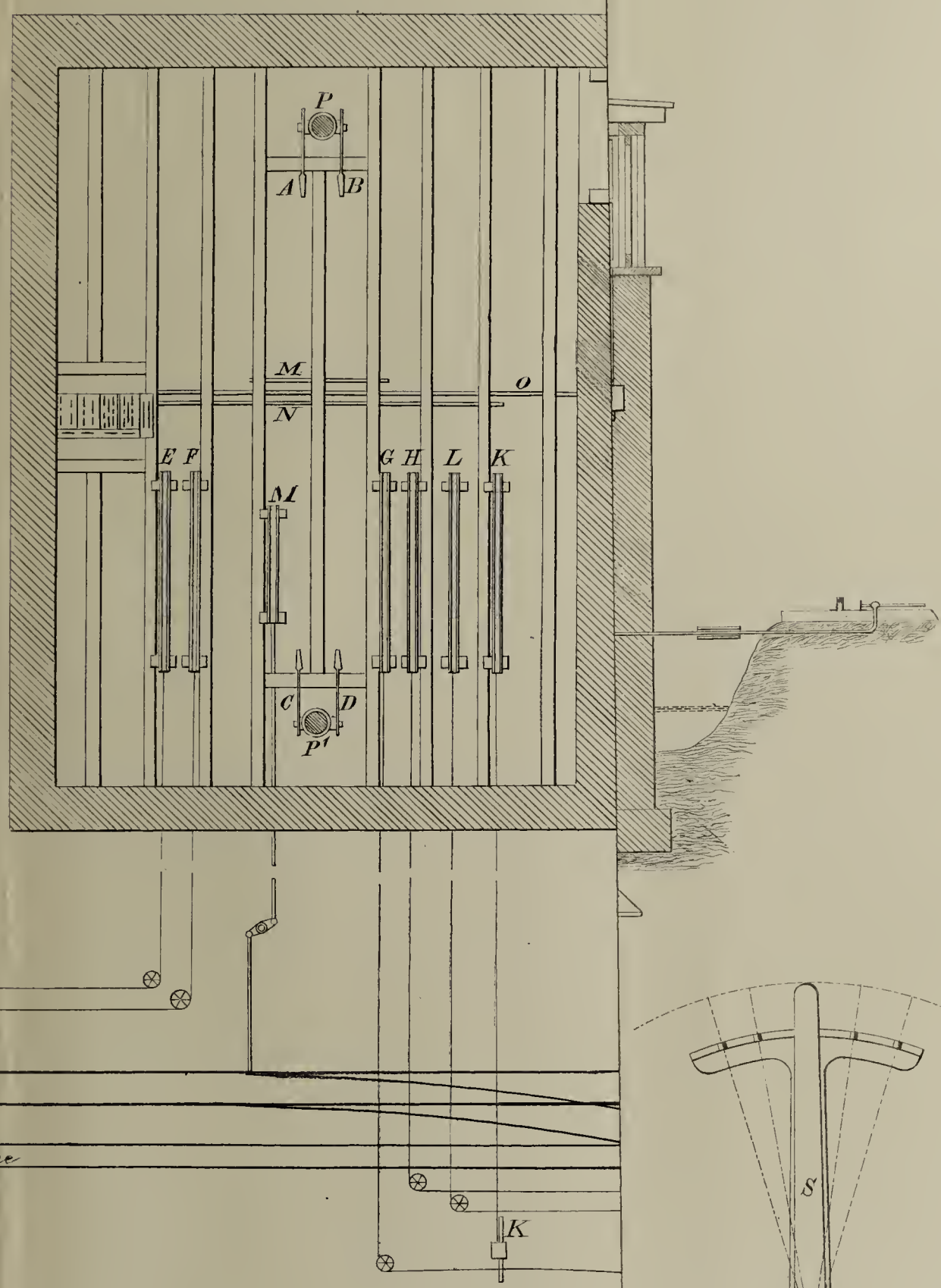
Fig. 222.



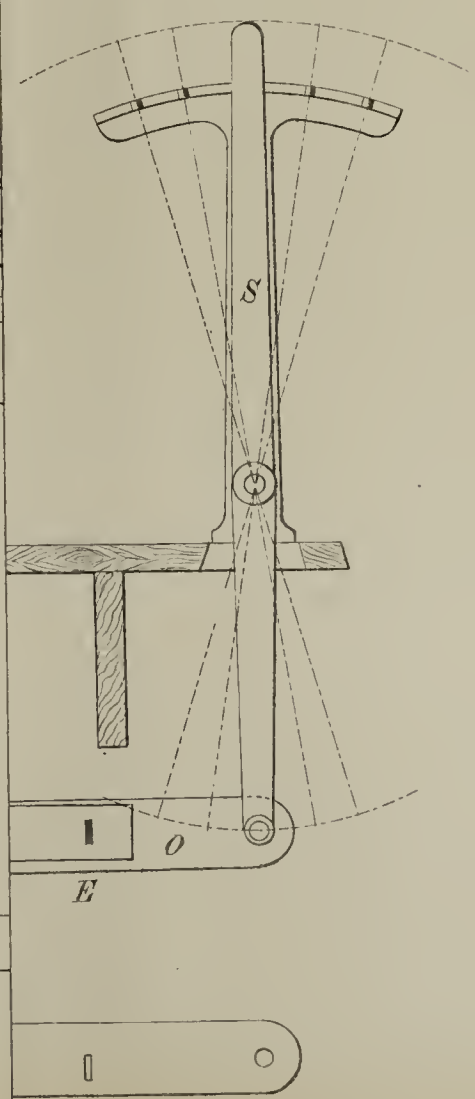


Fig. 224.

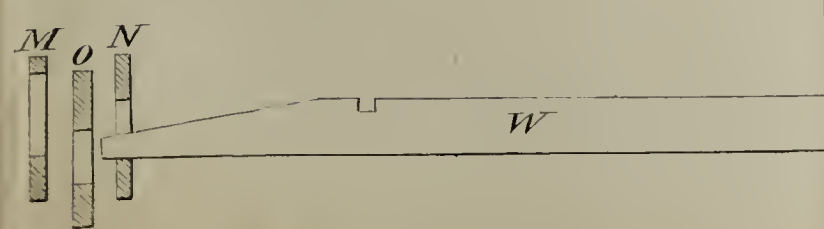


Fig. 217. Rapier.

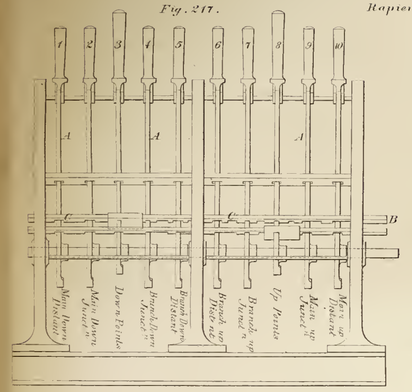


Fig. 218.

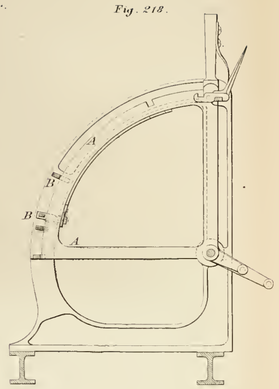


Fig. 219. Stevens

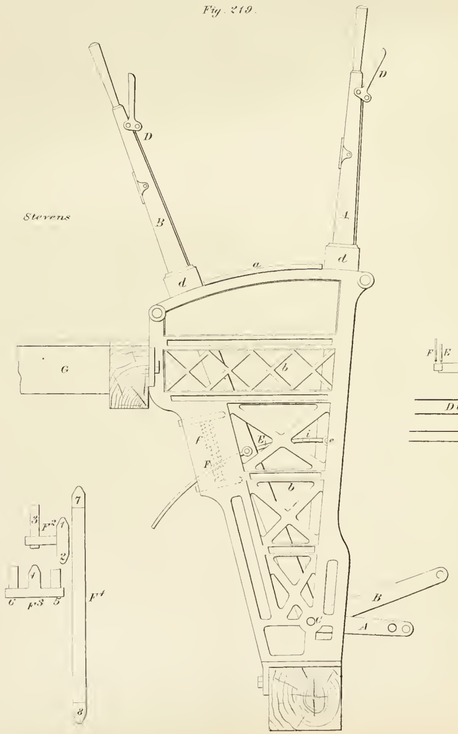


Fig. 222. Anderson

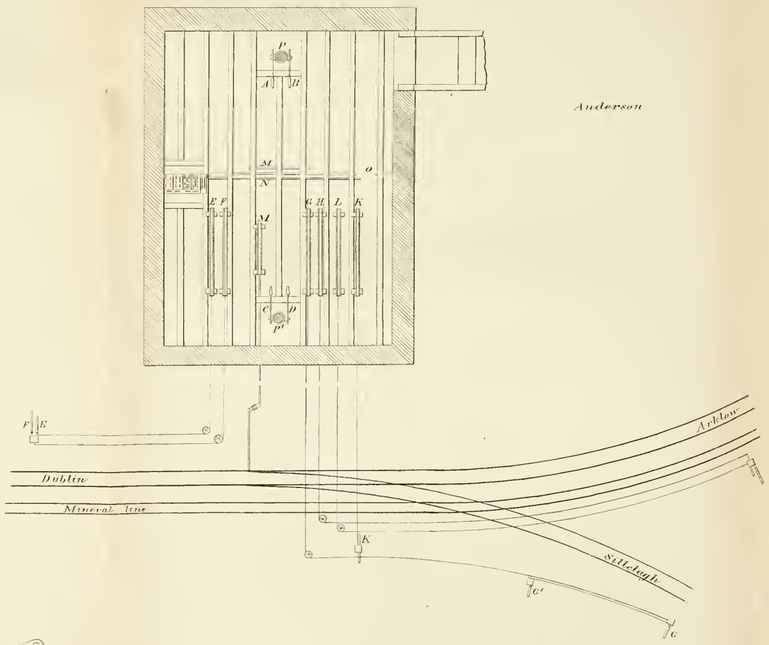


Fig. 223.

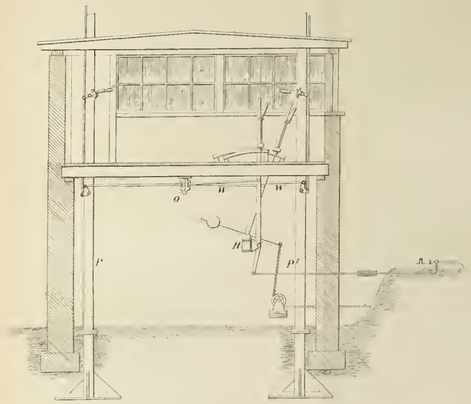


Fig. 216. Baines.

Fig. 221.

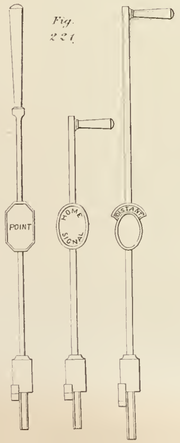


Fig. 220.

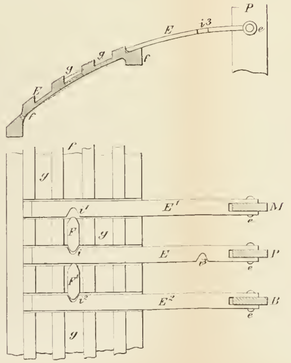
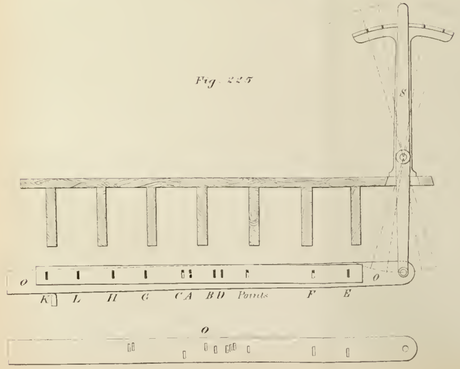
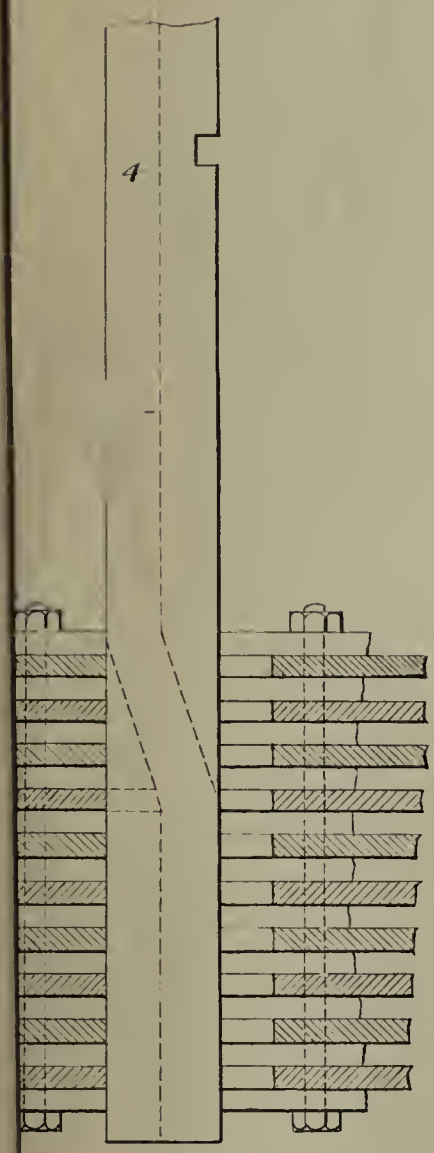


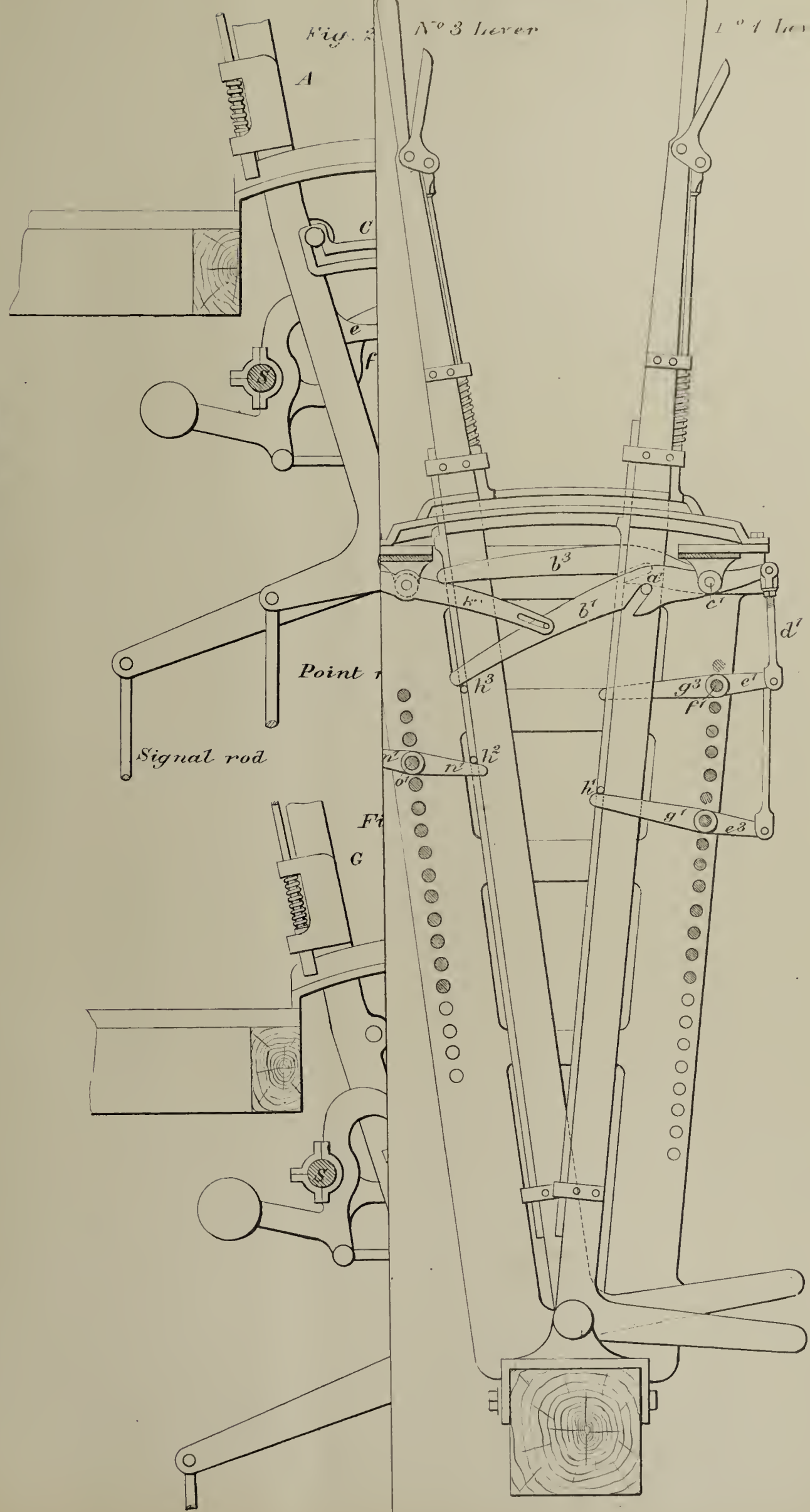
Fig. 224.

Fig. 225.



THE RAILWAY PRINTING & PUBLISHING COMPANY 12, CHANCE COURT FLEET STREET E.C.





COURT FLEET STREET E.C.

Fig. 226. Smith

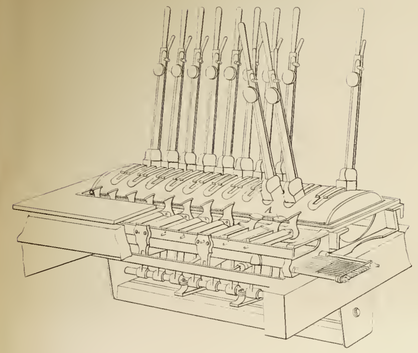
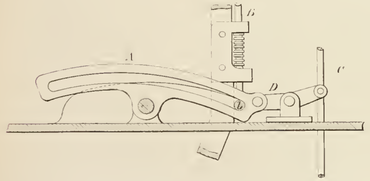


Fig. 227. Saxby. 1870.



Imray. 1872.

Fig. 230

Fig. 229.

Fig. 228.

Bailey

Fig. 231.

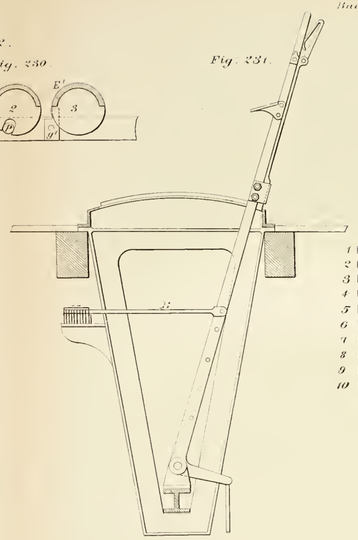


Fig. 232.

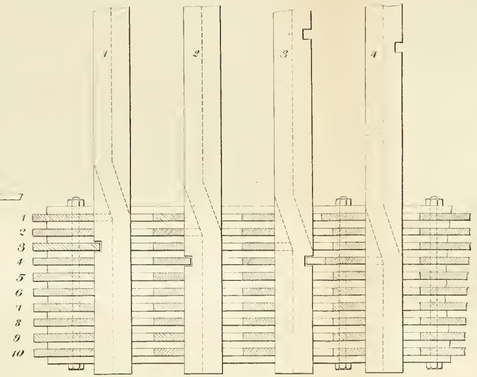
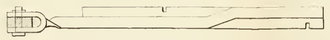


Fig. 233.



Saxby. 1871

Fig. 238.

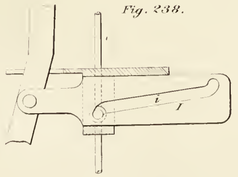
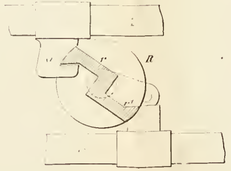


Fig. 239



McKenzie, Jones, & Holland.

Fig. 241

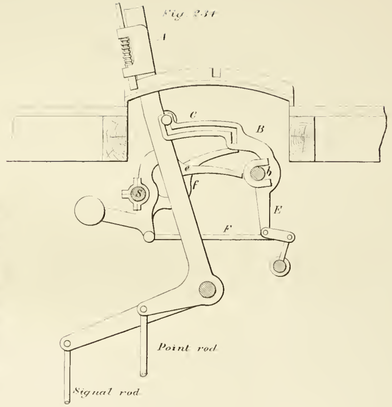
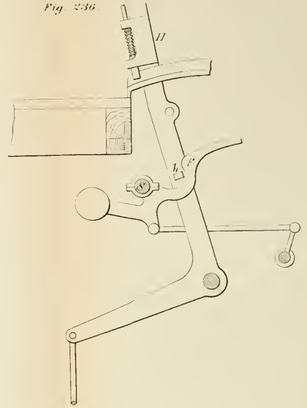


Fig. 236



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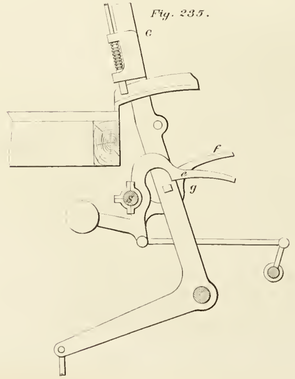


Fig. 237

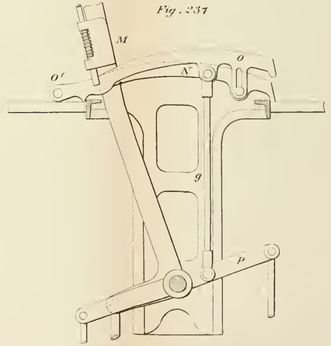
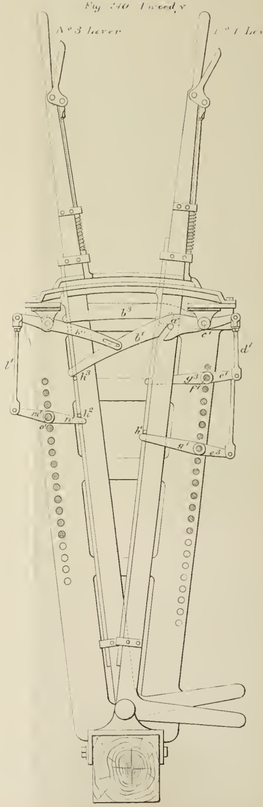


Fig. 240 Tweedy



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PERMANENT WAY.

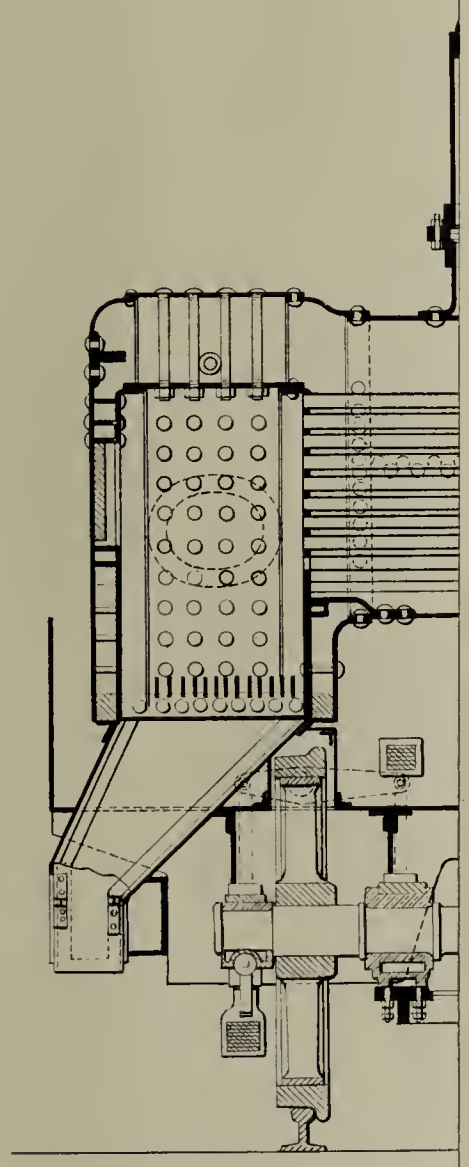
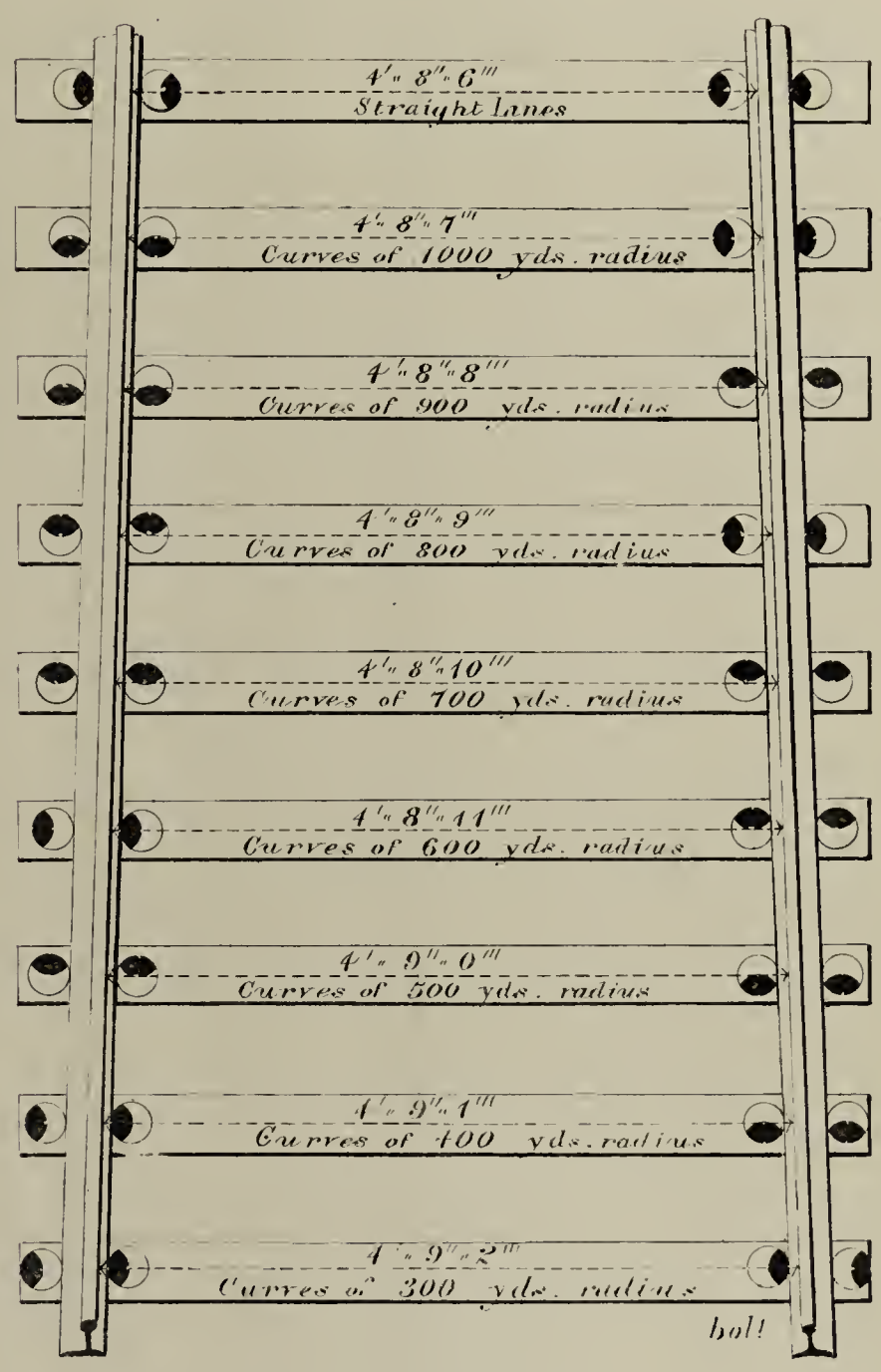


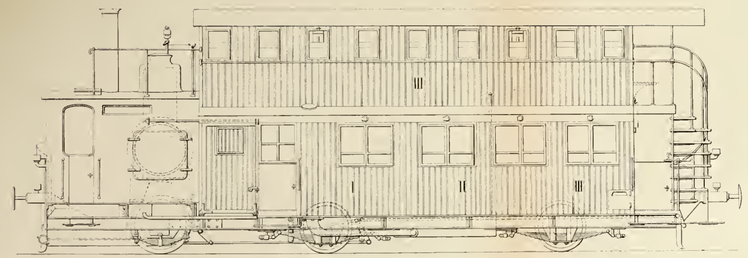
Fig. 8.
Diagram shewing position of bolts



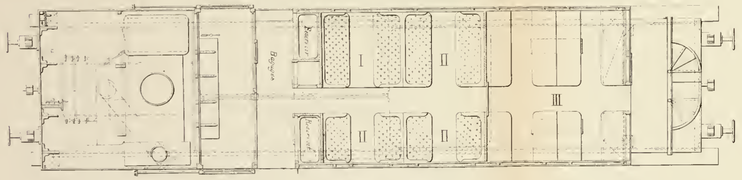
LIGHT RAILWAYS

G. THOMAS' STEAM CARRIAGE

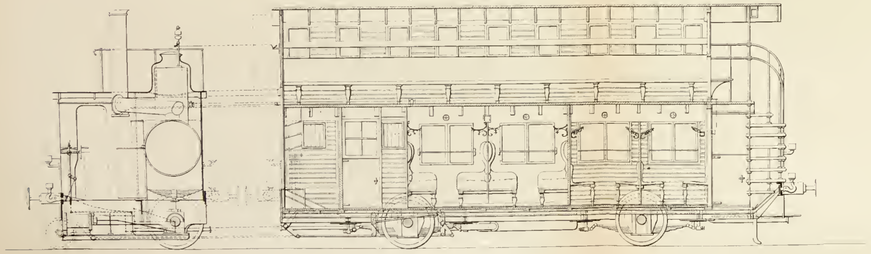
Longitudinal Elevation.



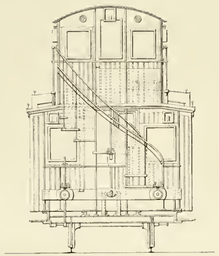
Plan.



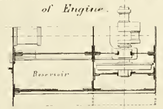
Longitudinal Section.



End View



Half Horizontal Section of Engine.



Front View.

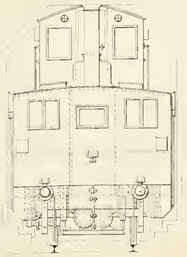
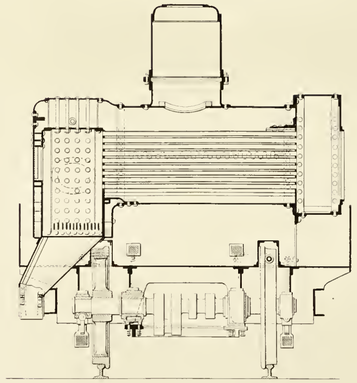


Fig. A.



IMPROVEMENTS IN PERMANENT WAY.

Fig. 1.

Fig. 2.

Fig. 3.

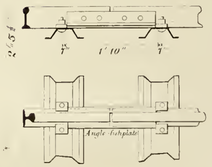


Fig. 4

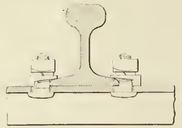


Fig. 5.

Fig. 6.

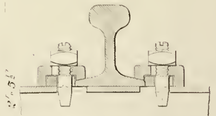
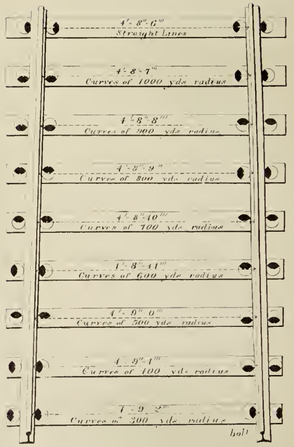


Fig. 7.

Fig. 8.
Diagram showing position of bolts



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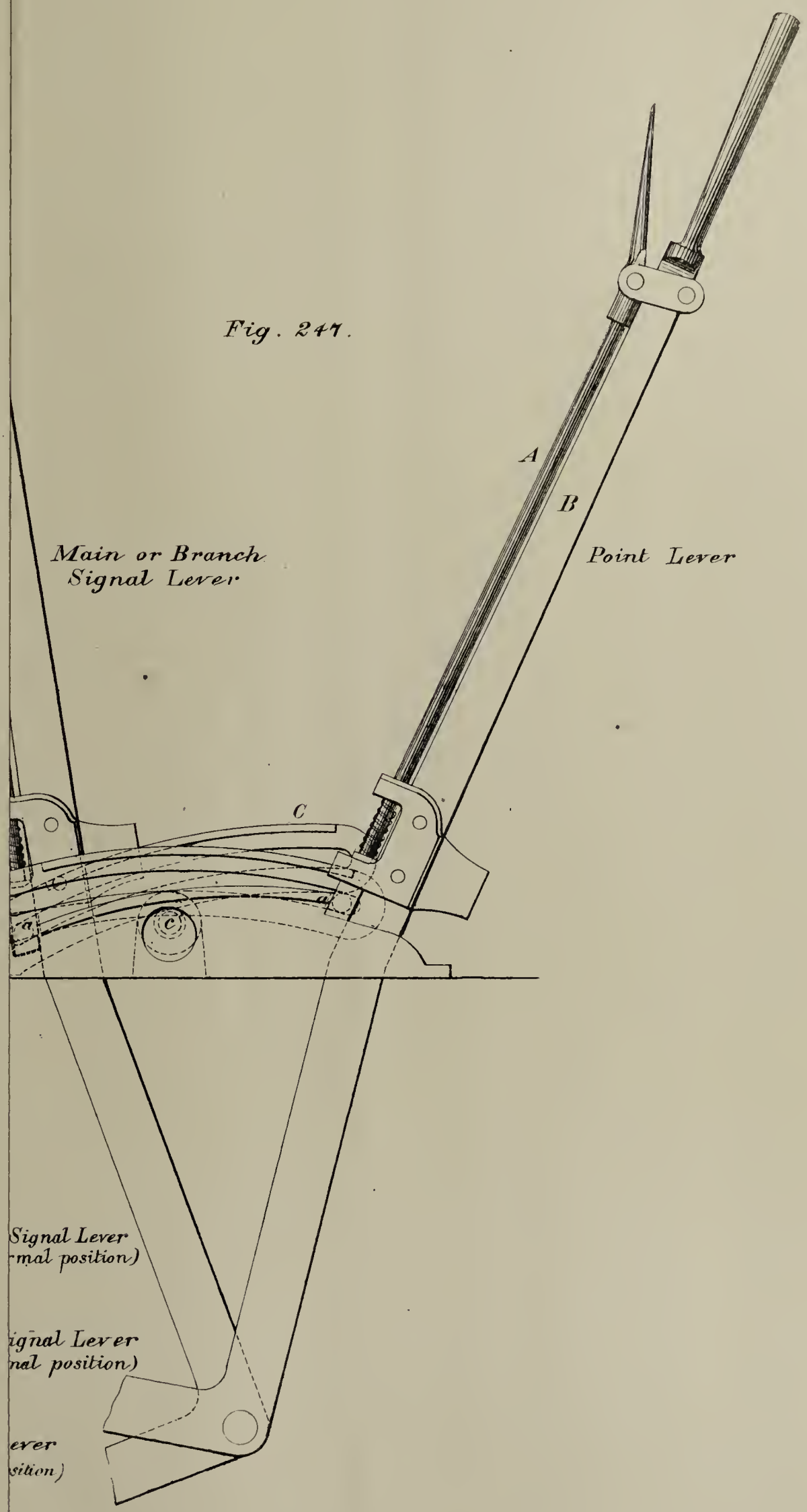
Fig. 247.
A
B
Point Lever
Main or Branch
Signal Lever
C
a
c
Signal Lever
mal position)
ignal Lever
nal position)
ever
sition)

Saxby & Farmer

Fig. 241

Fig. 242.

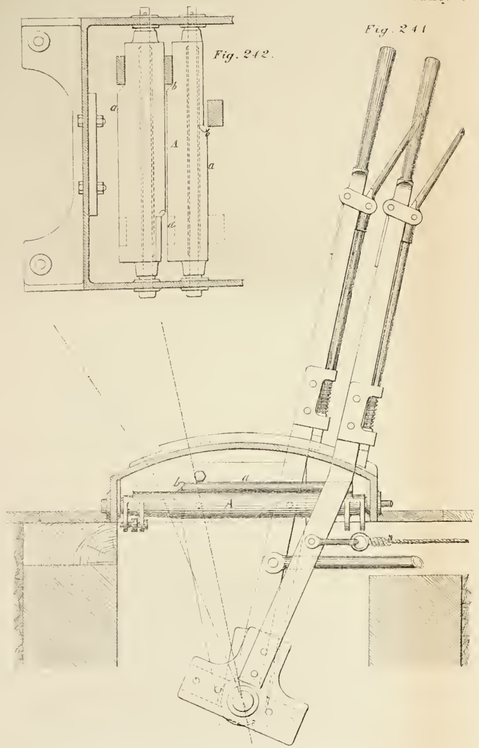

Fig. 143.

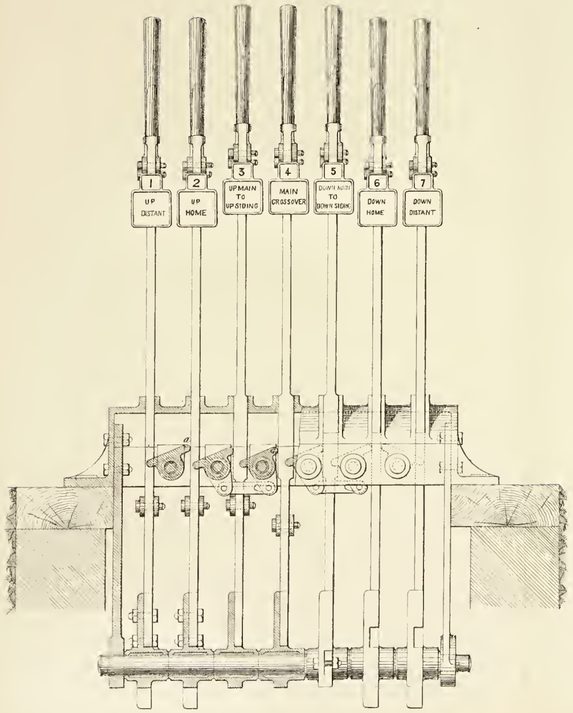

Fig. 244. Webb.

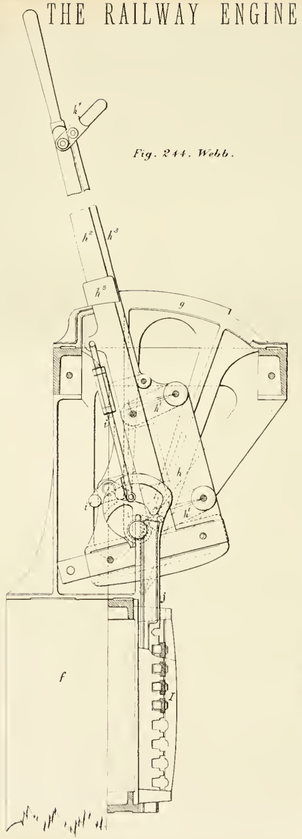

Fig. 246. Gt. West^n Rly.

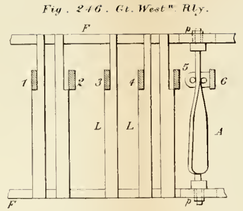

Fig. 249

Position 1.

Branch. Main. Point.

Position 2.

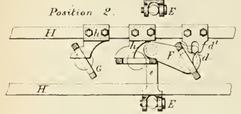

Fig. 243.

Saxby & Farmer's most recent Apparatus

Fig. 247

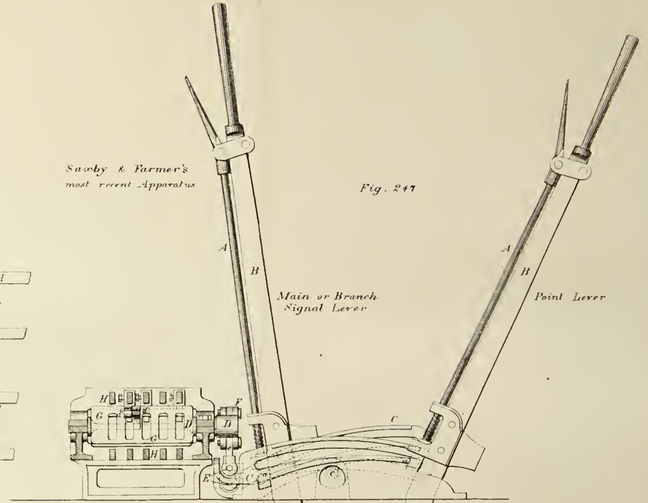

Fig. 248. Plan.

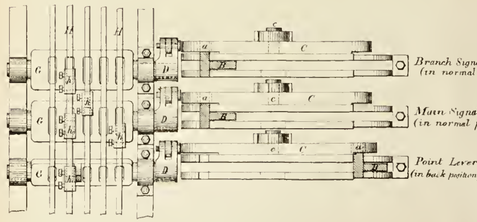

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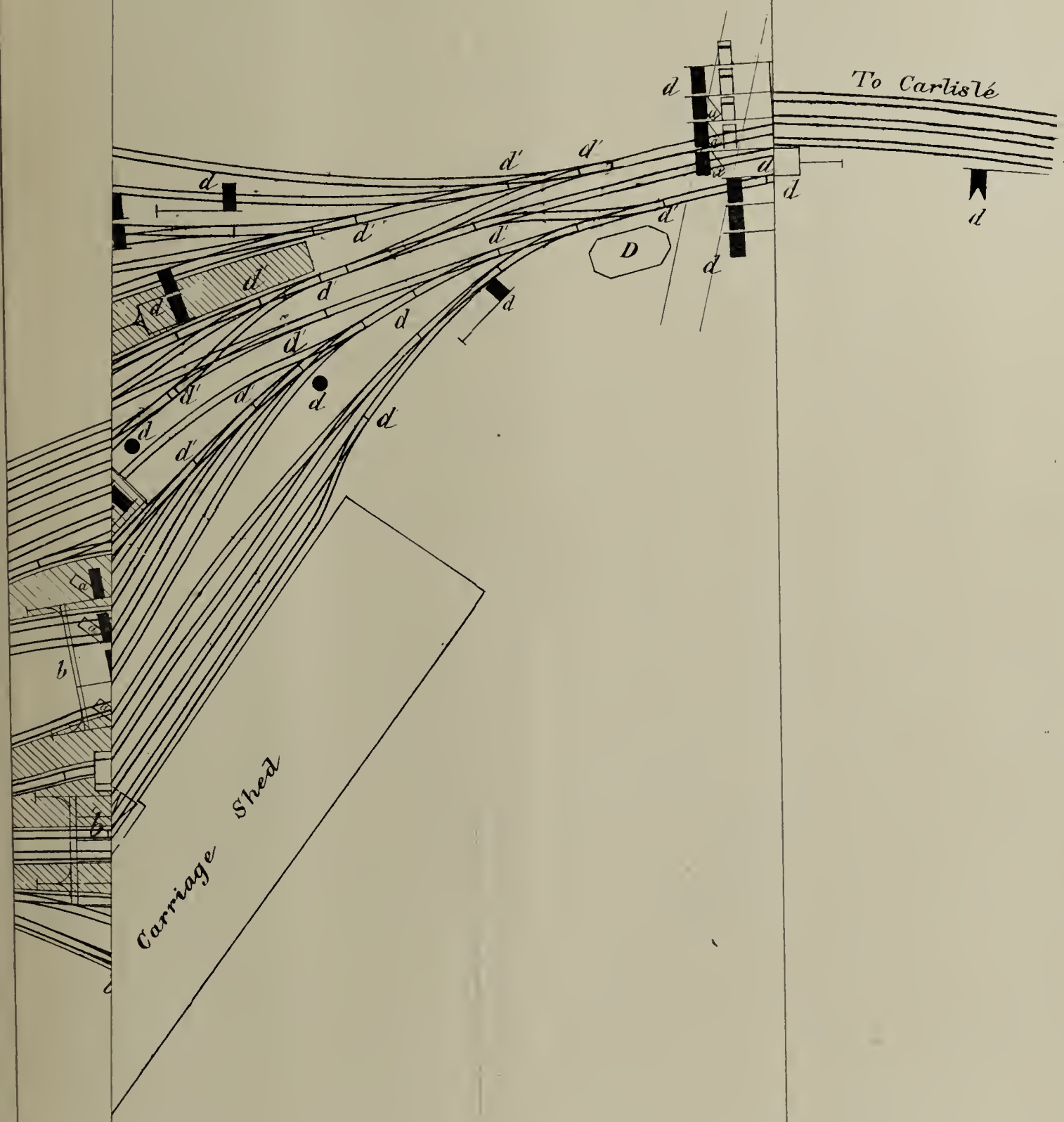
PLATE CLIV

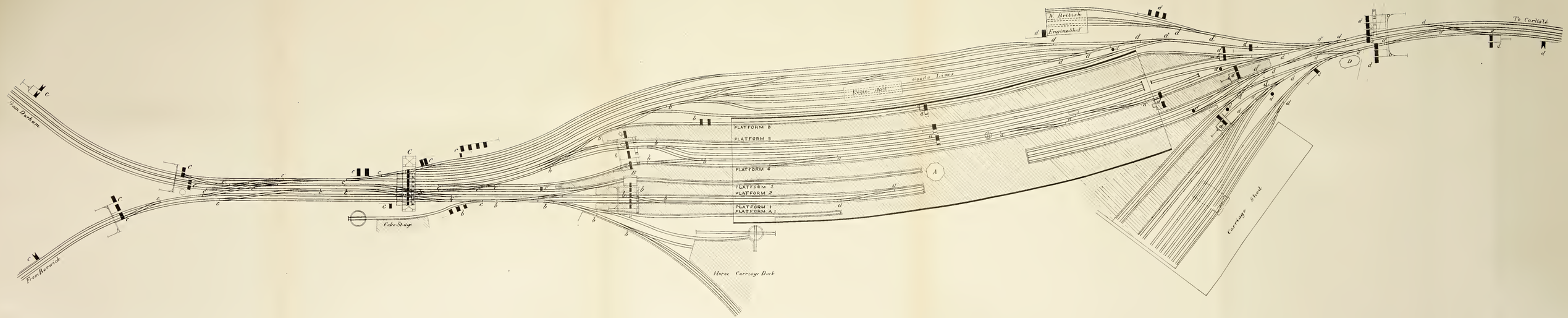


RAILWAY SIGNALLING—INTERLOCKING

Fig. 250.

N.E.R. Central Station

Newcastle-on-Tyne.



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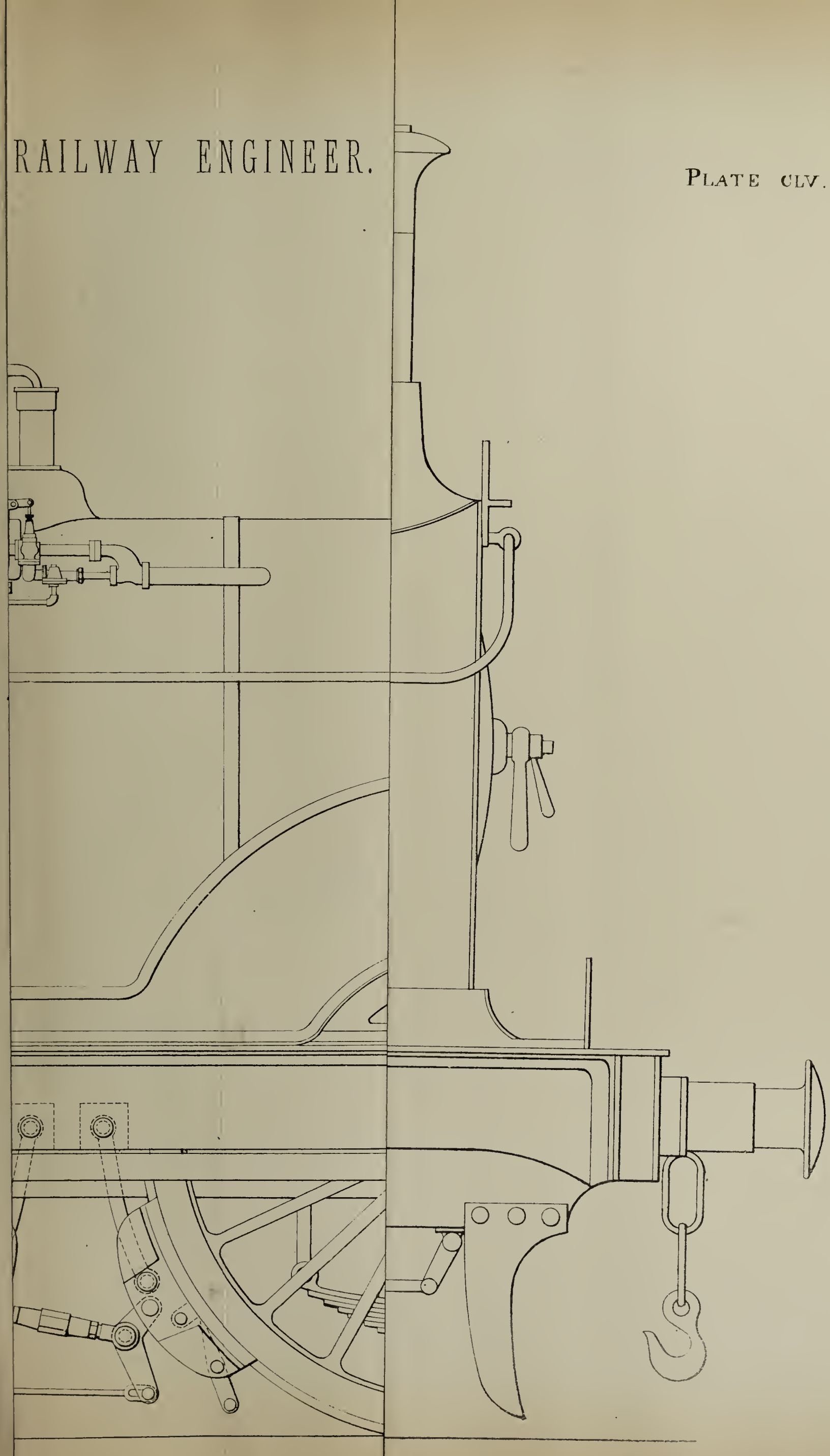
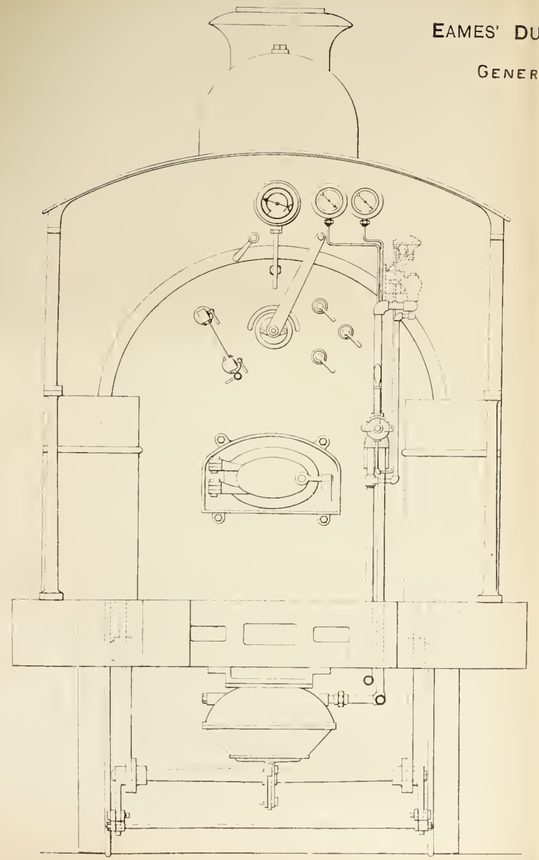
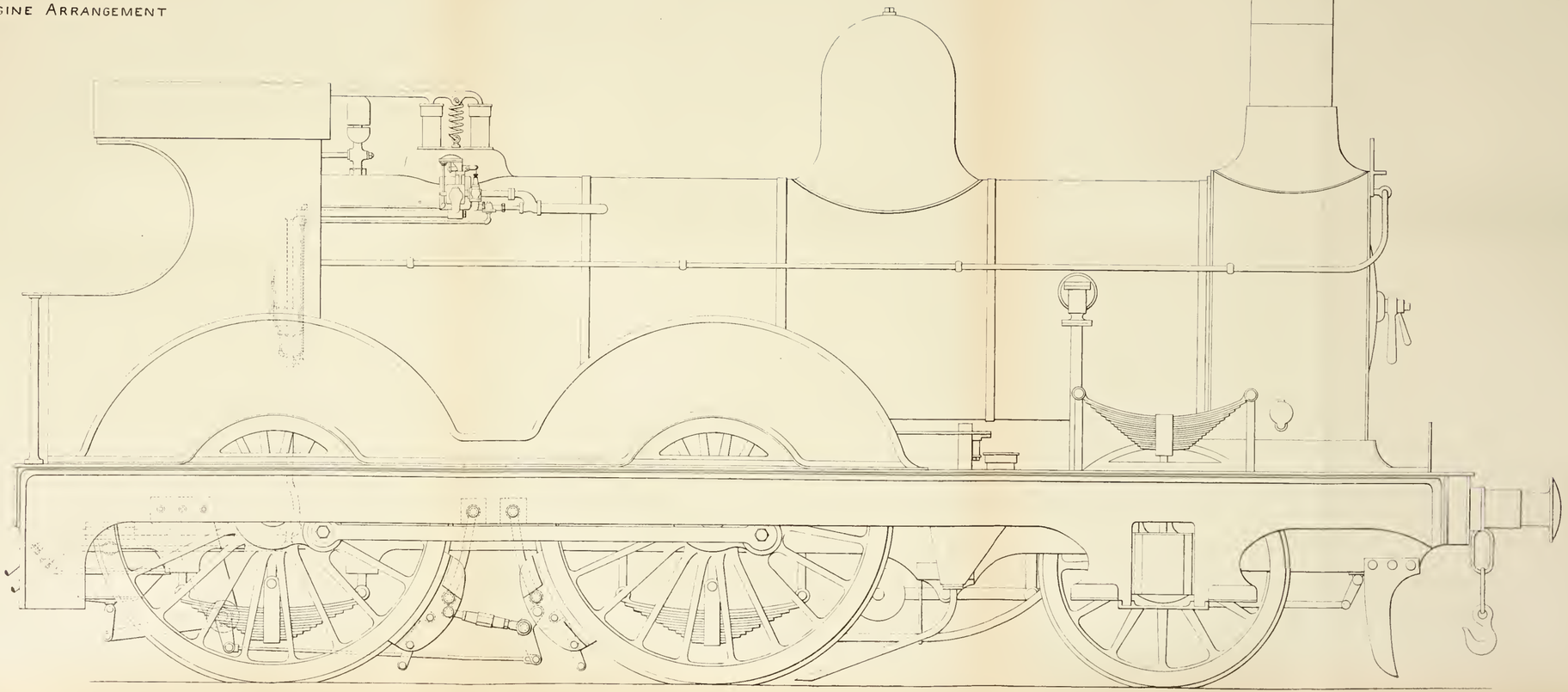
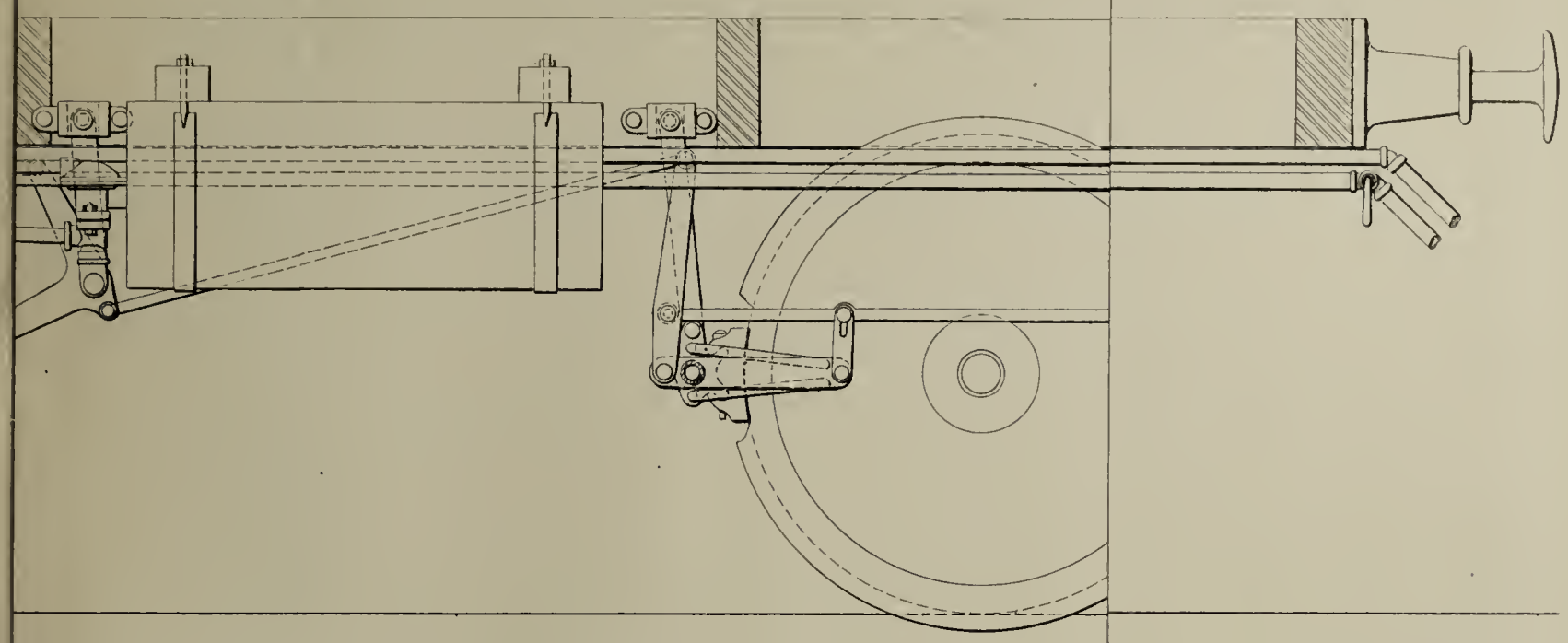


EAMES' DUPLEX AUTOMATIC VACUUM BRAKE.

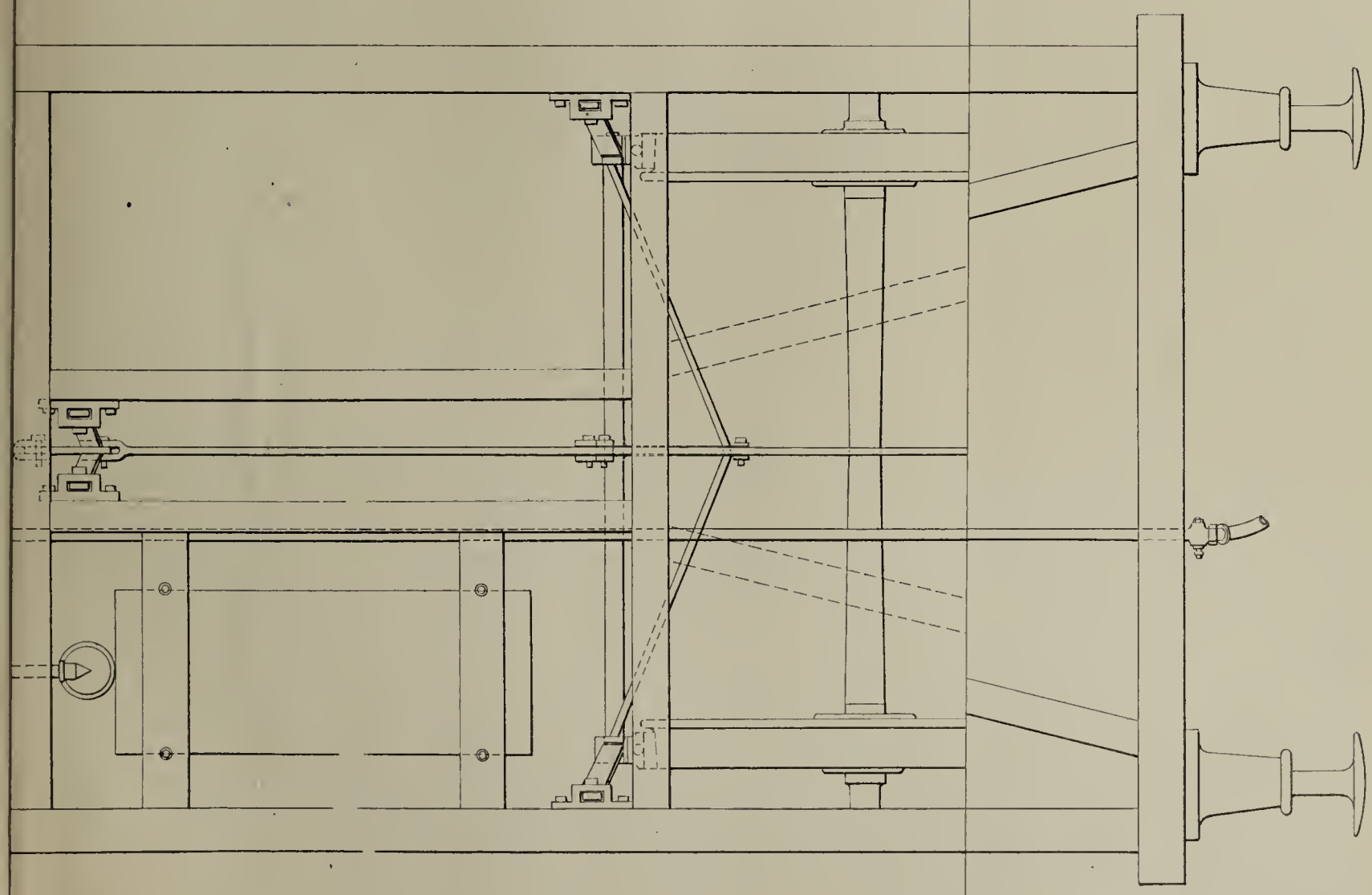
GENERAL ENGINE ARRANGEMENT





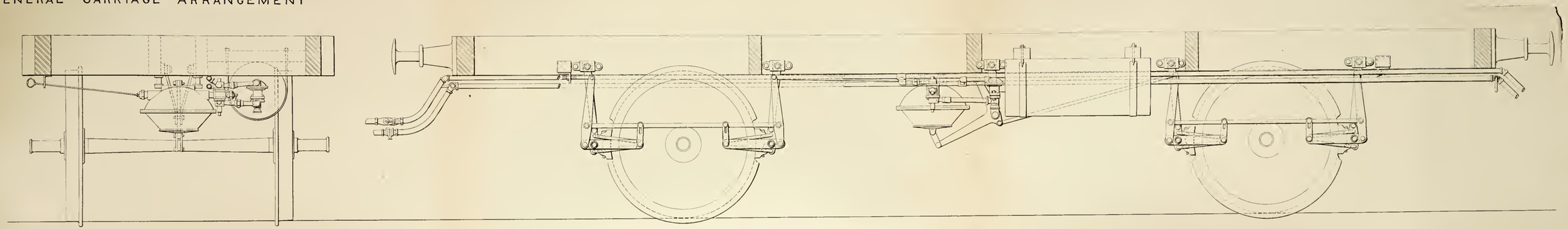


PLAN

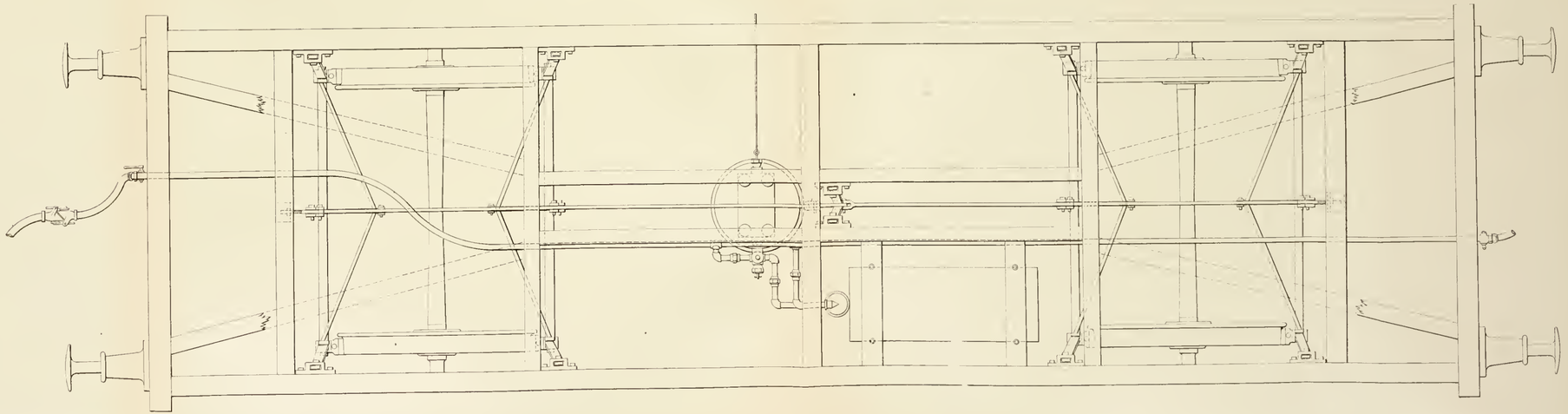


EAMES' DUPLEX AUTOMATIC VACUUM BRAKE.

GENERAL CARRIAGE ARRANGEMENT



PLAN



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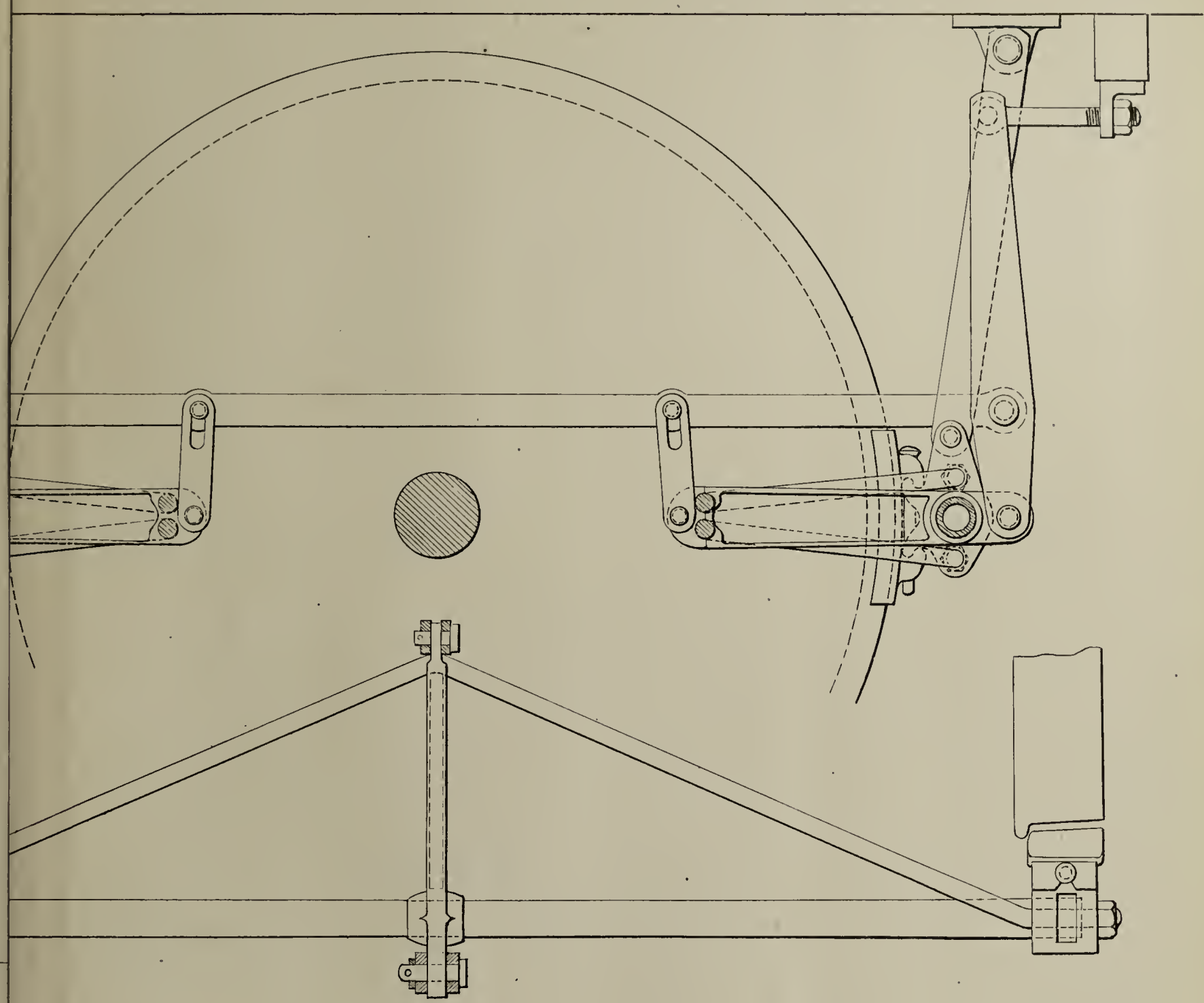
2. STANDARD FOUNDATION BRAKE GEAR.



EAVER'S VALVE.

FIG. 5. REST.

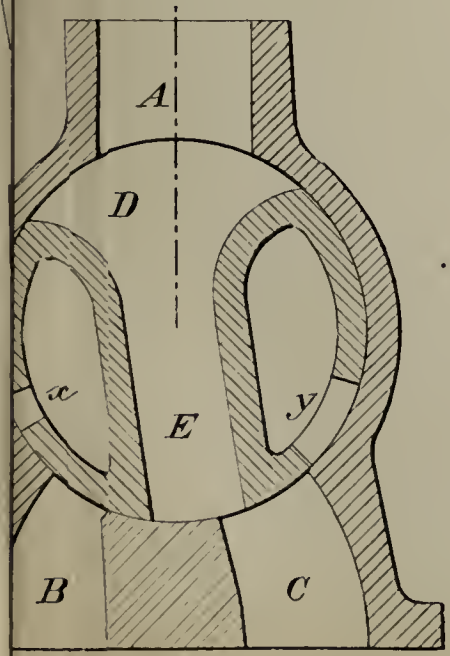


FIG. 4. OFF.

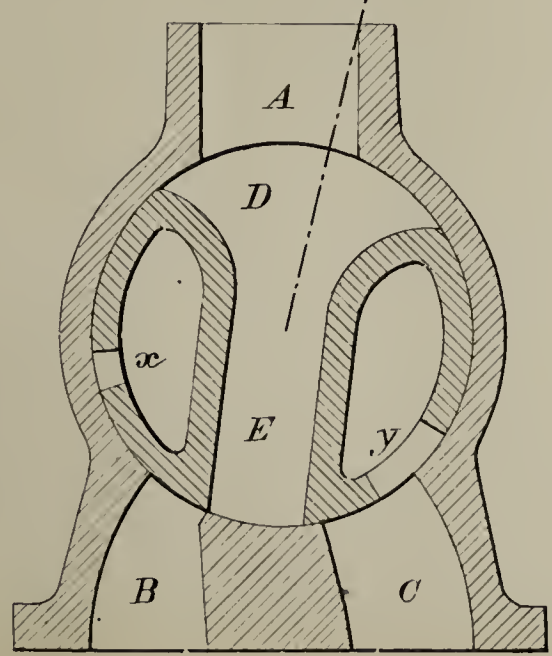


FIG. 3. FULL OFF.

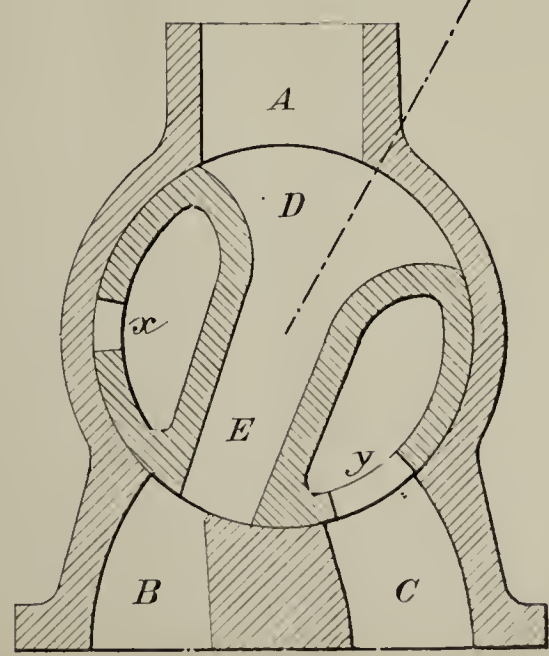


FIG. 1.
EJECTOR.

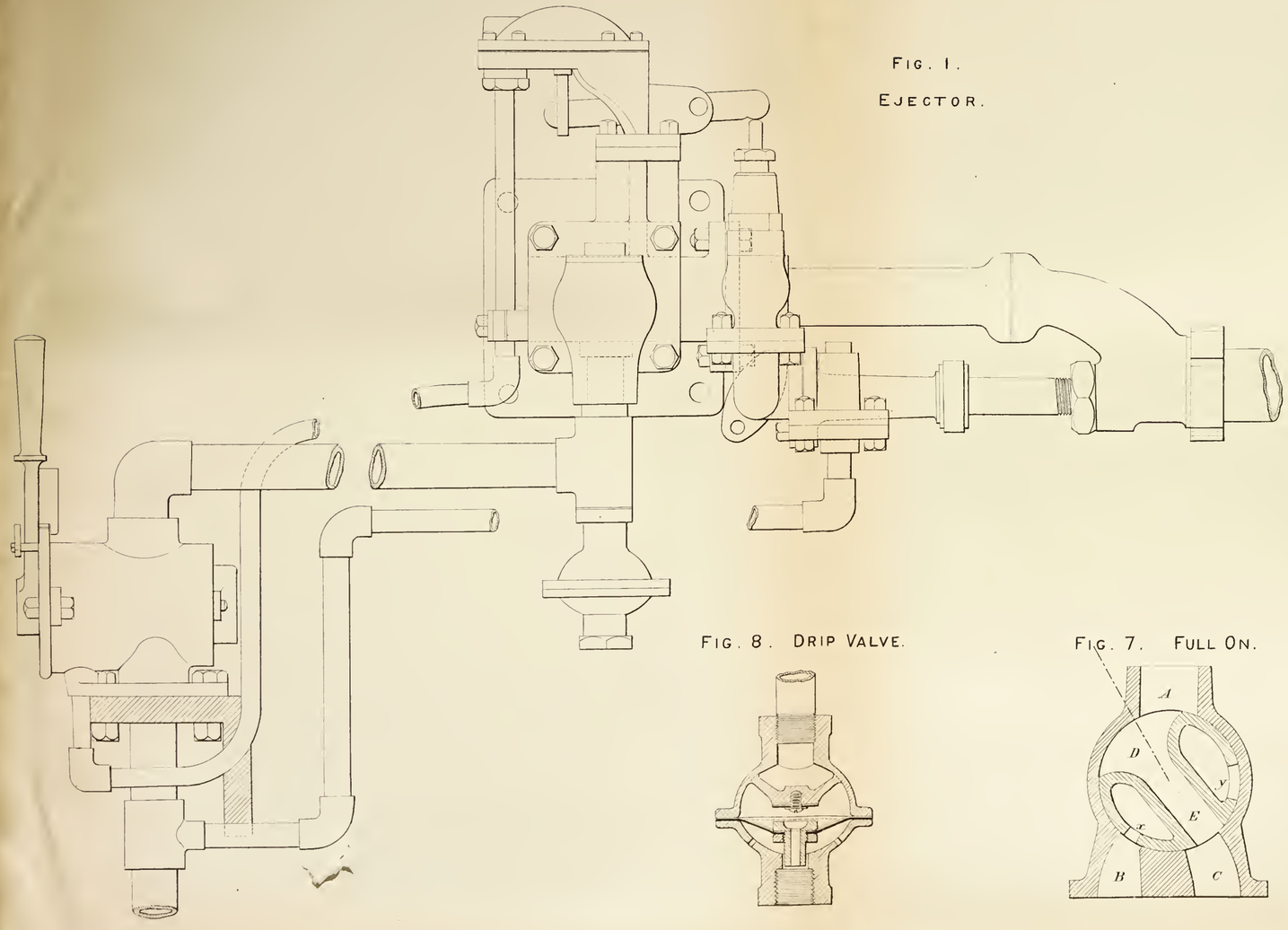


FIG. 2. STANDARD FOUNDATION BRAKE GEAR.

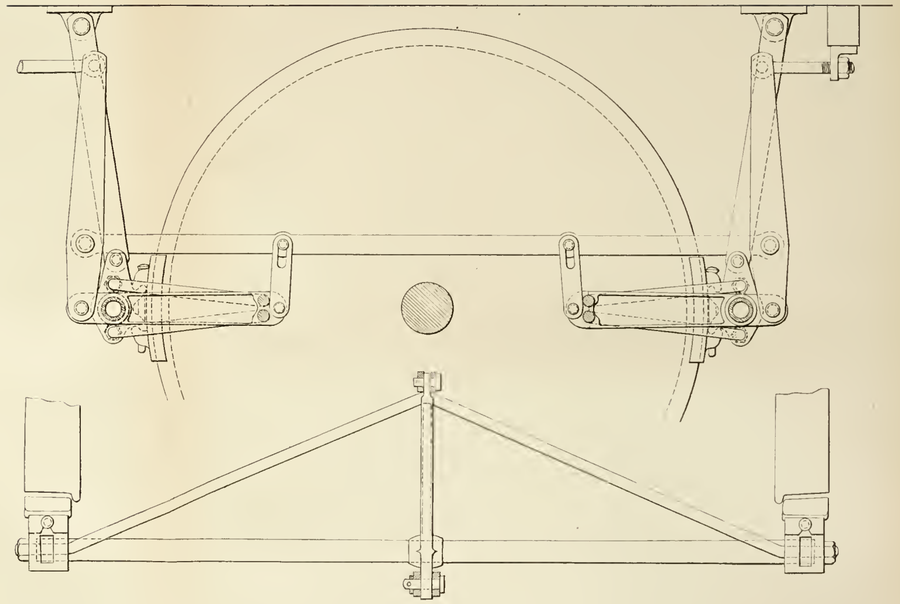
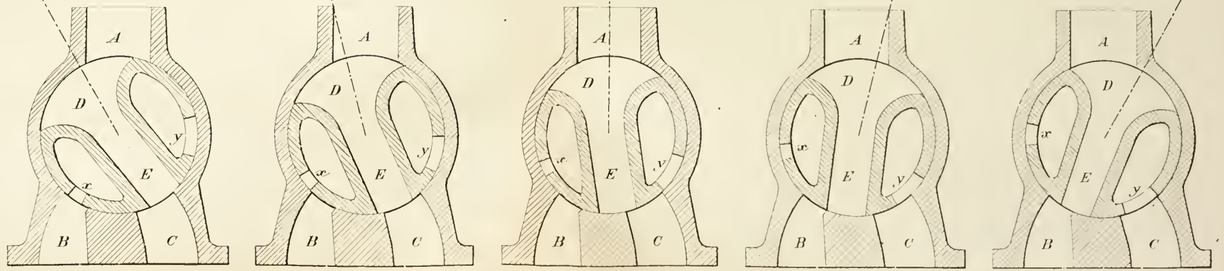


FIG. 8. DRIP VALVE.

DRIVER'S VALVE.

FIG. 7. FULL ON. FIG. 6. ON. FIG. 5. REST. FIG. 4. OFF. FIG. 3. FULL OFF.



THE RAILWAY PRINTING & PUBLISHING COMPANY, 12, CRANE COURT, FLEET STREET, E.C.

f 1884.

Fig. 252.

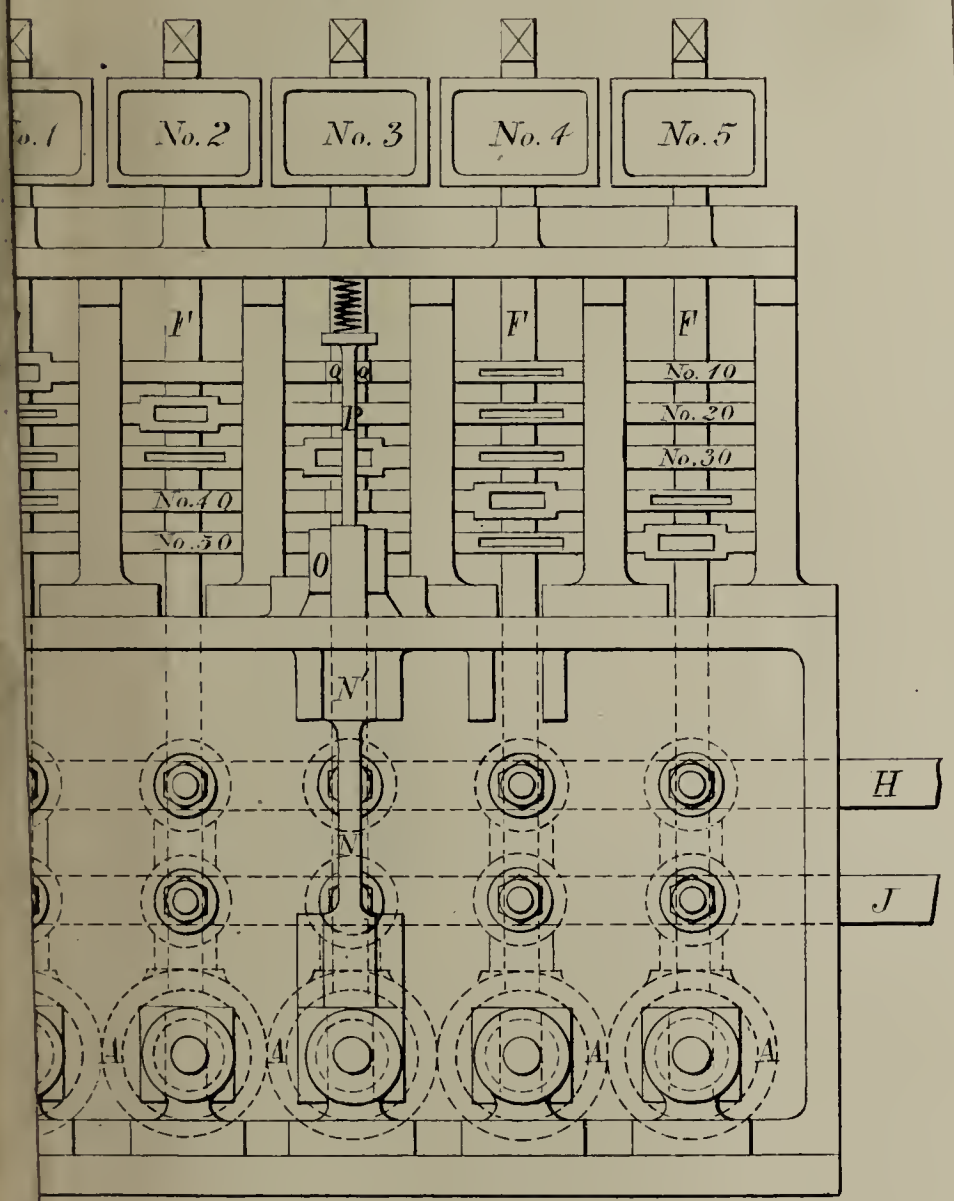
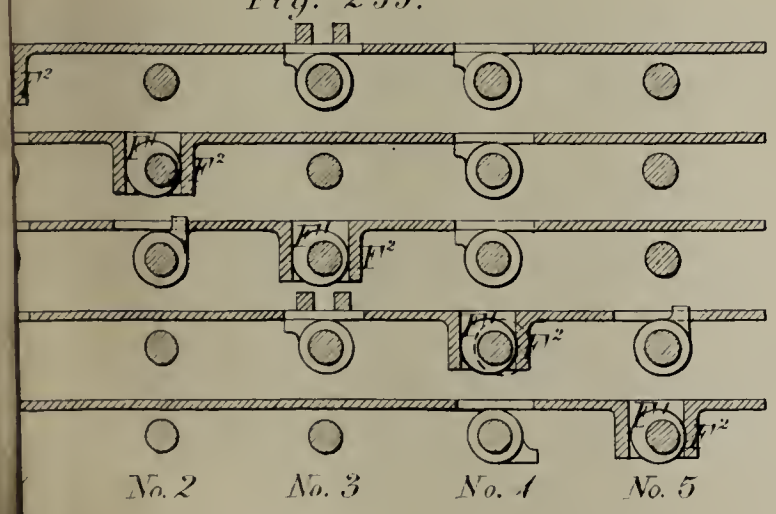


Fig. 255.



THE RAILWAY ENGINEER.

Edward's Frame.
(The Railway Signal Co. Lim.)

Fig. 251.

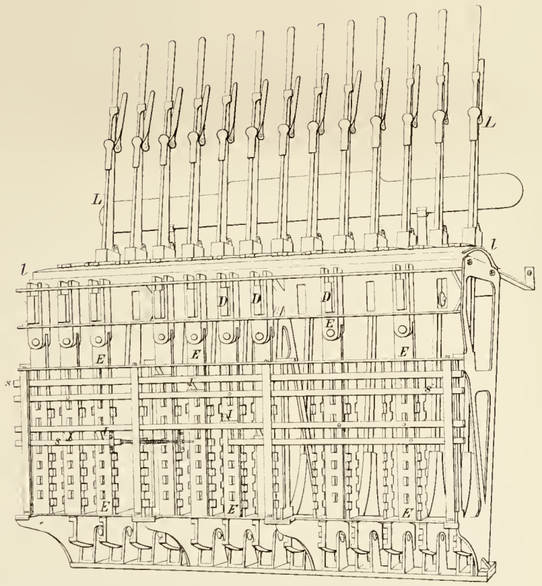
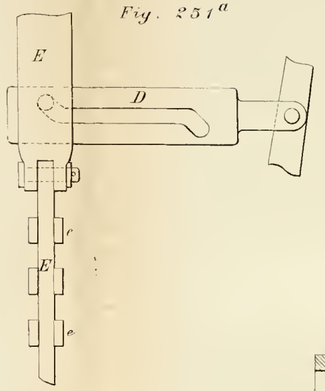


Fig. 251a



Brush's Hydraulic Interlocking Frame of 1884.

Fig. 253.

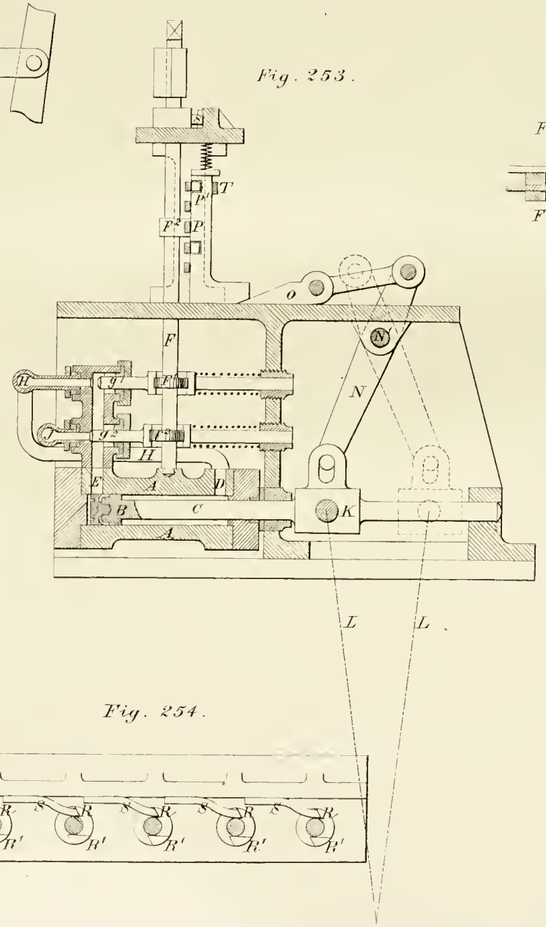


Fig. 254.

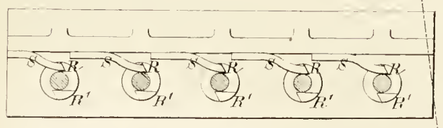


Fig. 256.

Fig. 252.

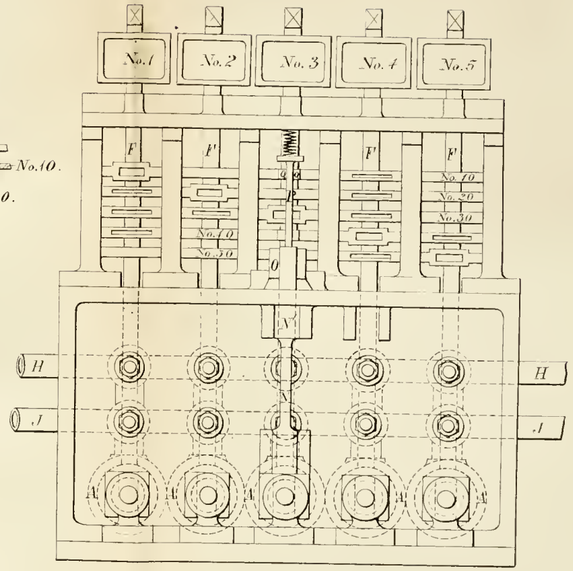


Fig. 255.

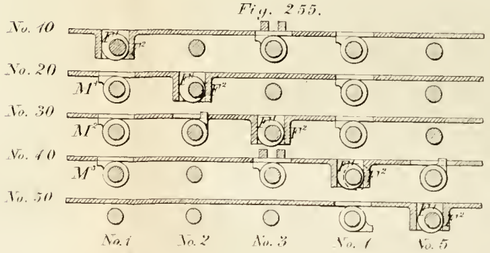
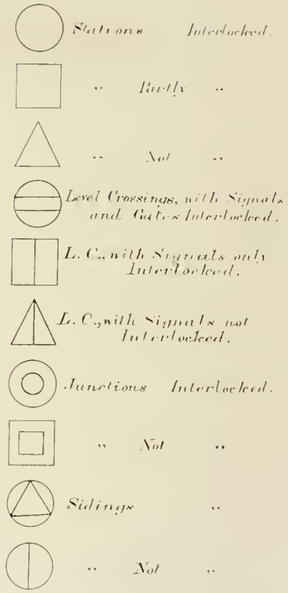


Fig. 257.



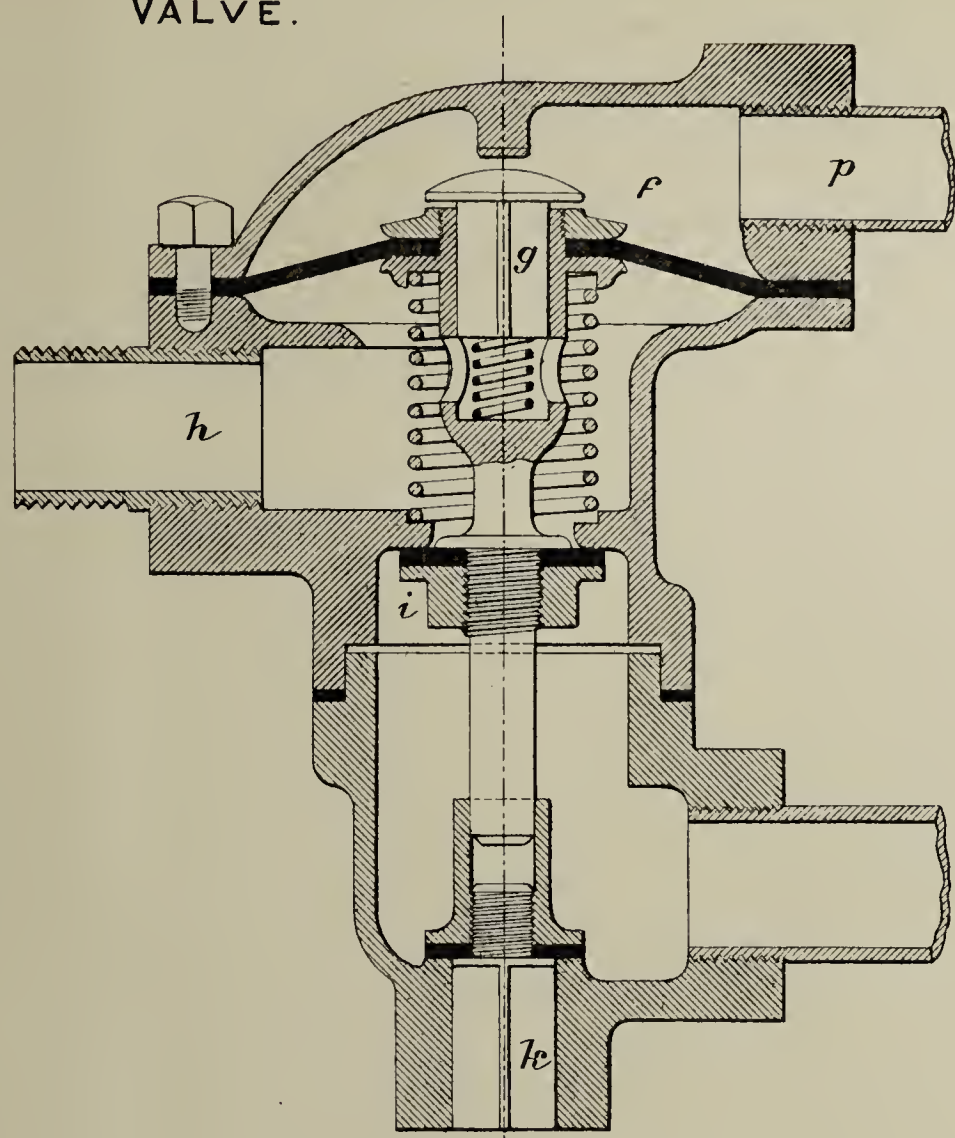
THE RAILWAY PRINTING & PUBLISHING COMPANY, 12, CRANE COURT, FLEET STREET, E.C.

THE

PLATE CLIX

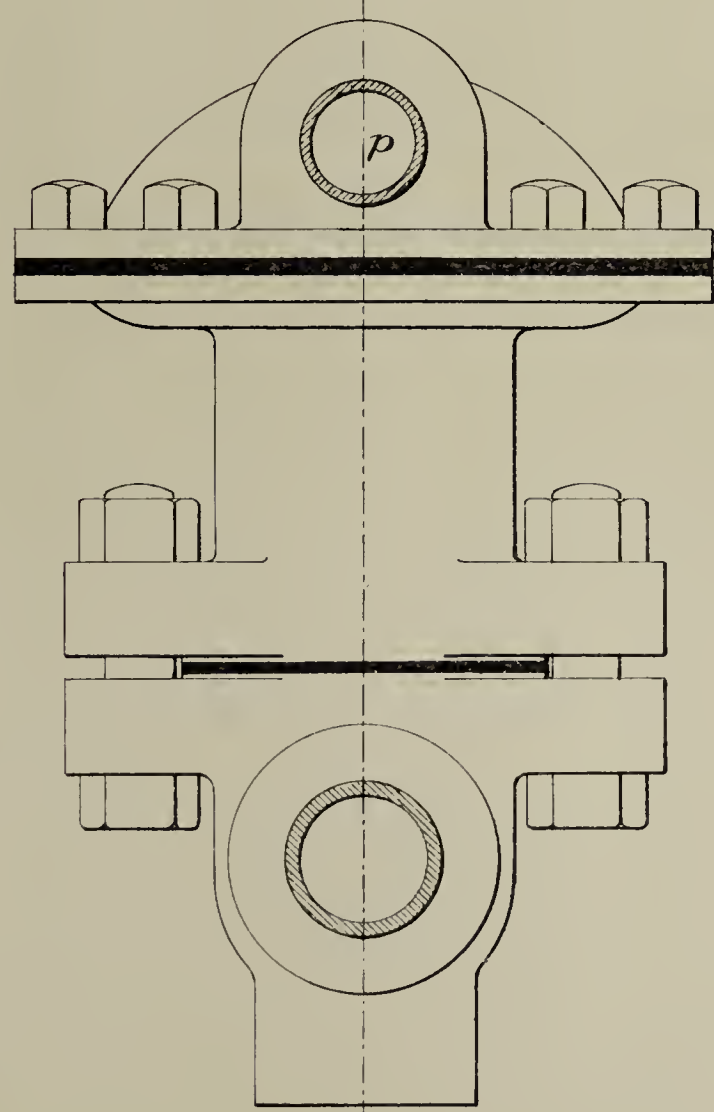
DUPLEX VALVE.

FIG. 11.



ew.

FIG. 12.



EAMES' DUPLEX AUTOMATIC VACUUM BRAKE.

EJECTOR.

FIG. 1.

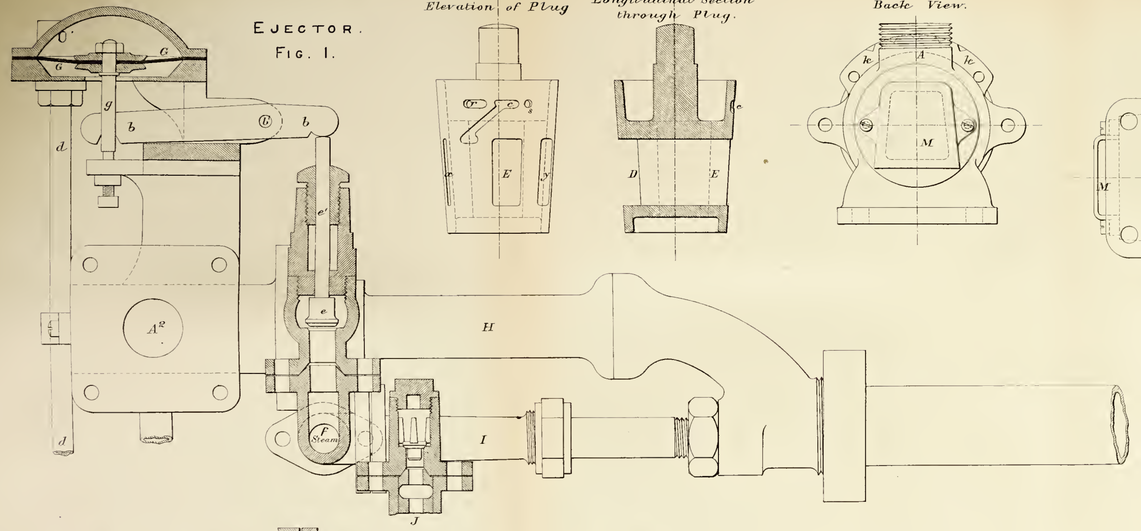
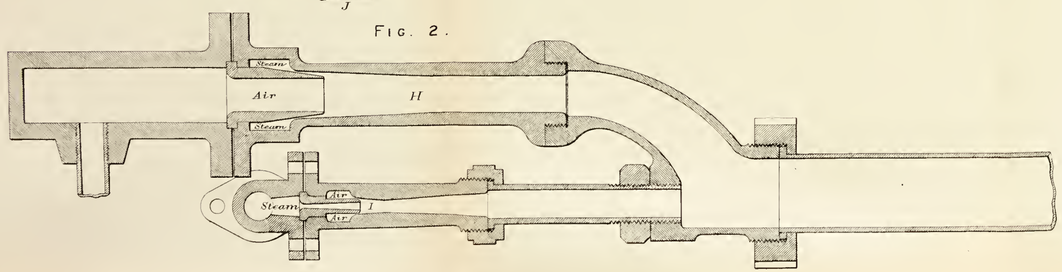


FIG. 9.
Elevation of Plug

FIG. 8.
Longitudinal Section through Plug.

FIG. 7.
Back View.

FIG. 2.



DRIVER'S VALVE.

FIG. 6.
Bottom View.

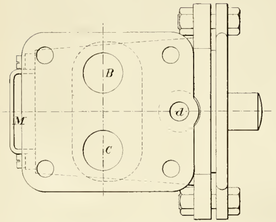


FIG. 10.
Transverse Section through Plug.

FIG. 3.
Sectional Elevation

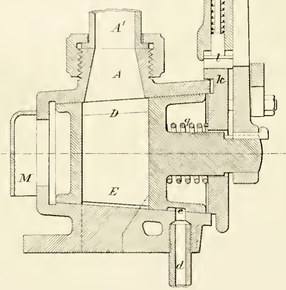


FIG. 4.
Side Elevation.

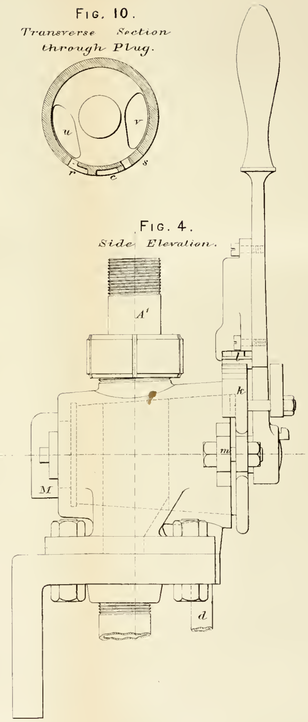
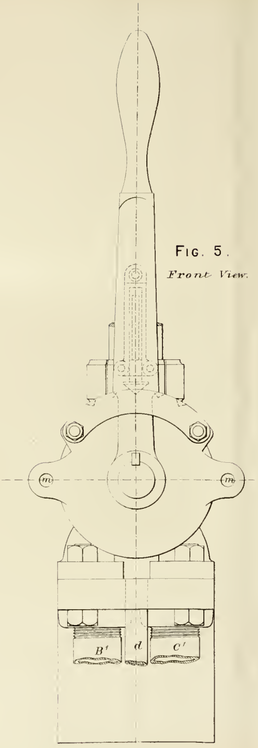


FIG. 5.
Front View.



DUPLEX VALVE.

FIG. 11.

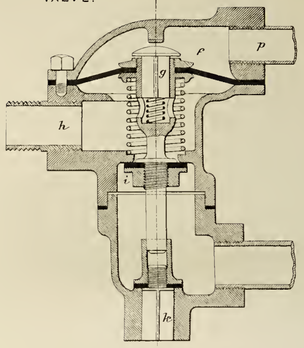
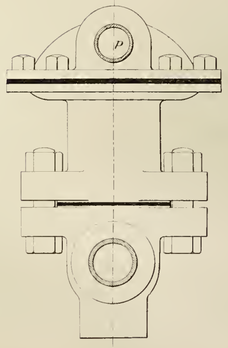


FIG. 12.

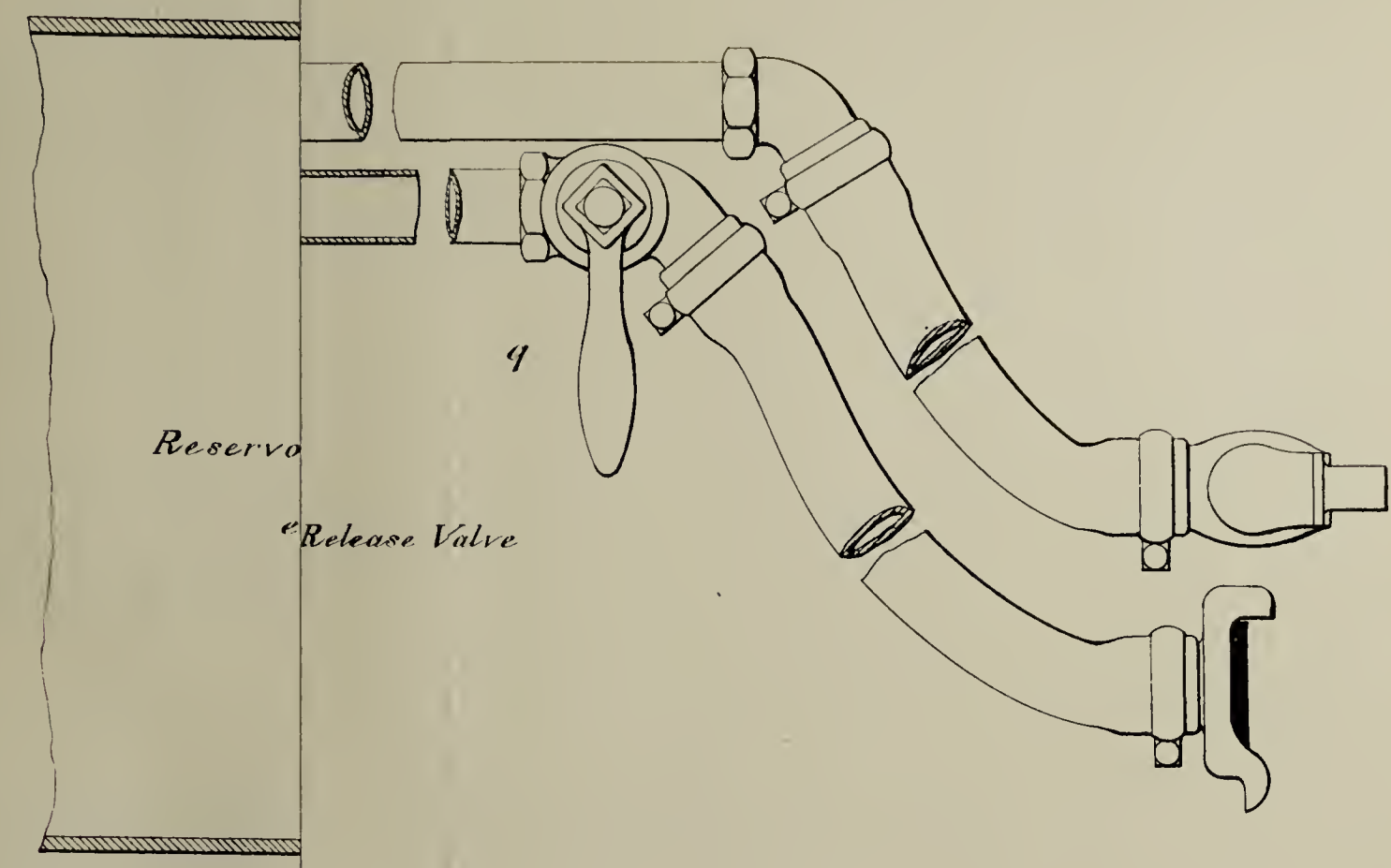


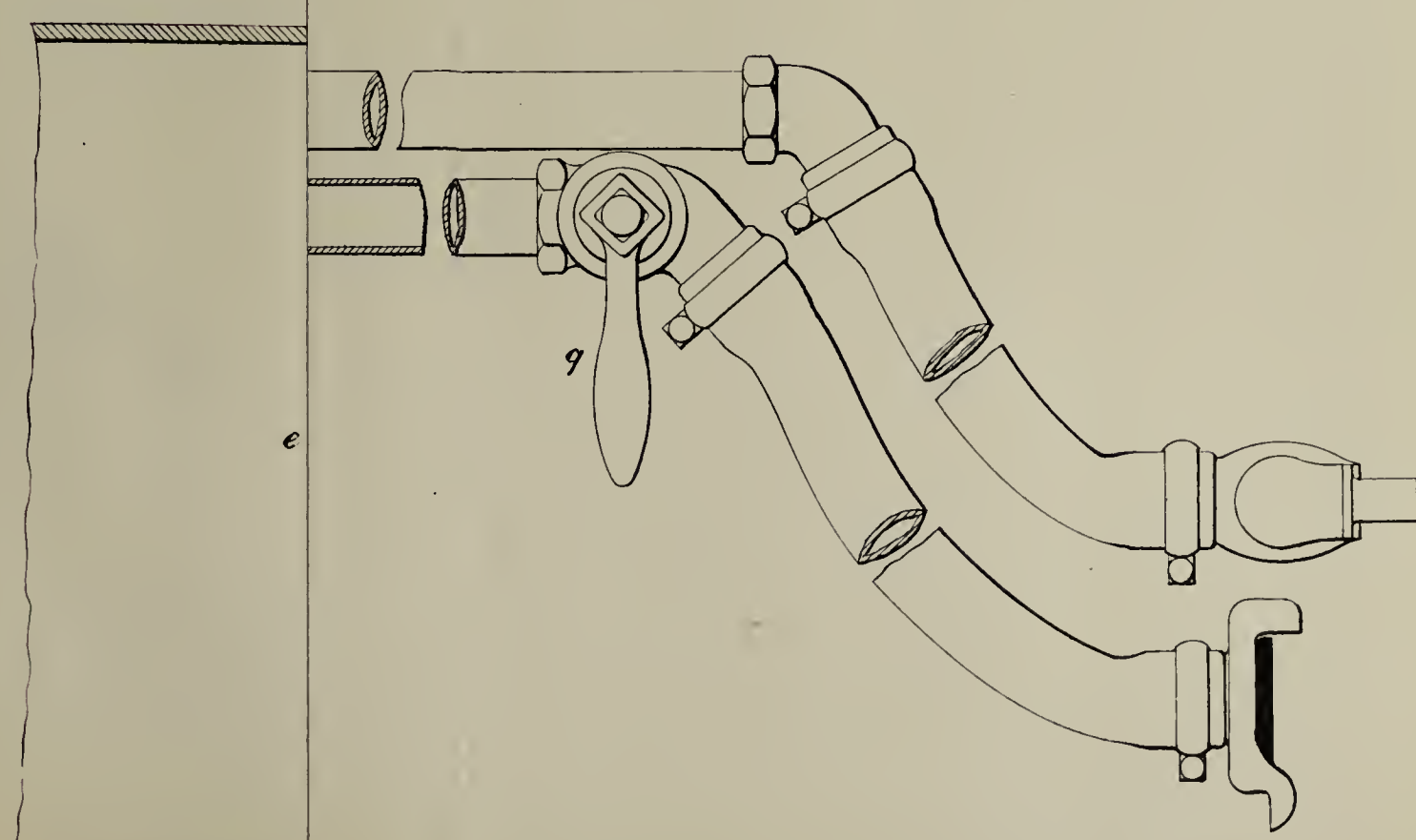
THE RAILWAY PRINTING & PUBLISHING COMPANY, 12, ORANGE COURT, FLEET STREET, E.C.

EAMES' DUPLEX

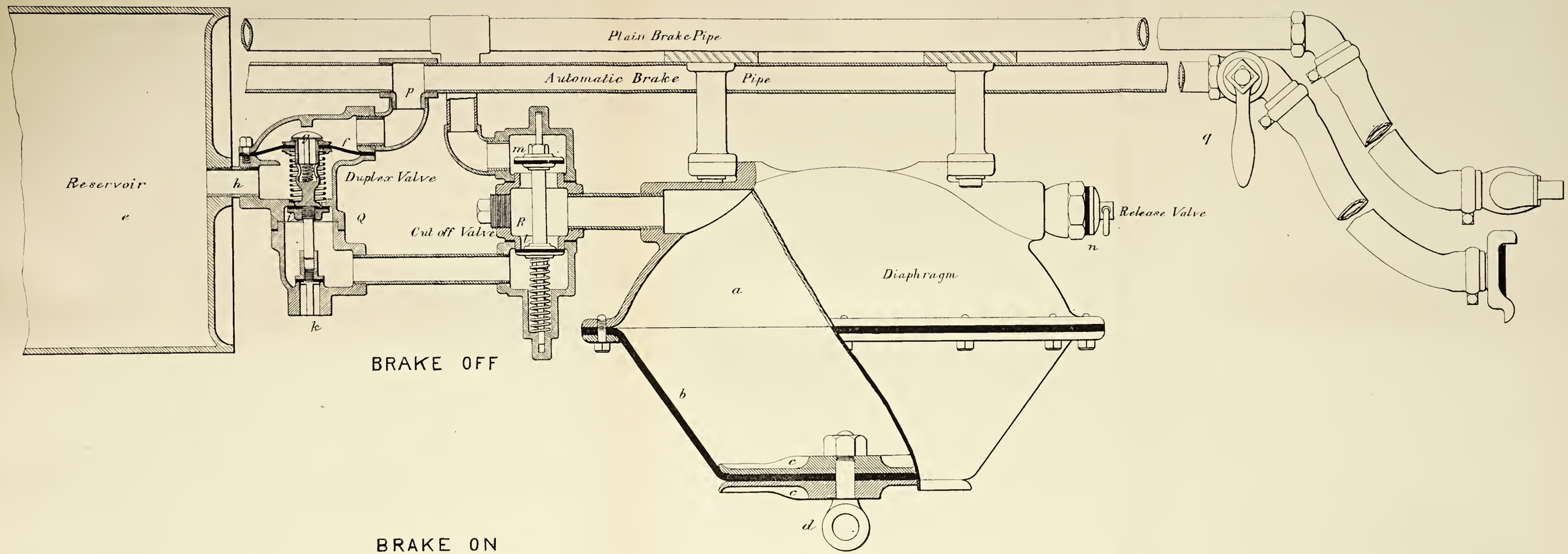
OP

PLATE CLX



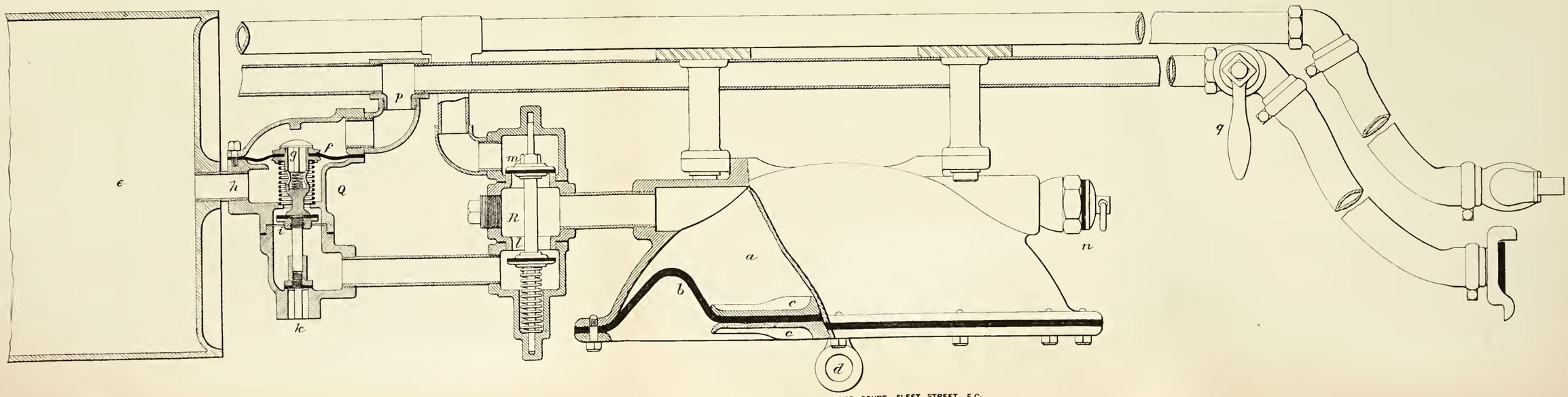


OPERATION OF PARTS



BRAKE OFF

BRAKE ON



THE RAILWAY PRINTING & PUBLISHING COMPANY, 12, CRANE COURT, FLEET STREET, E.C.

Fig. 13. Plan of Permanent Way.

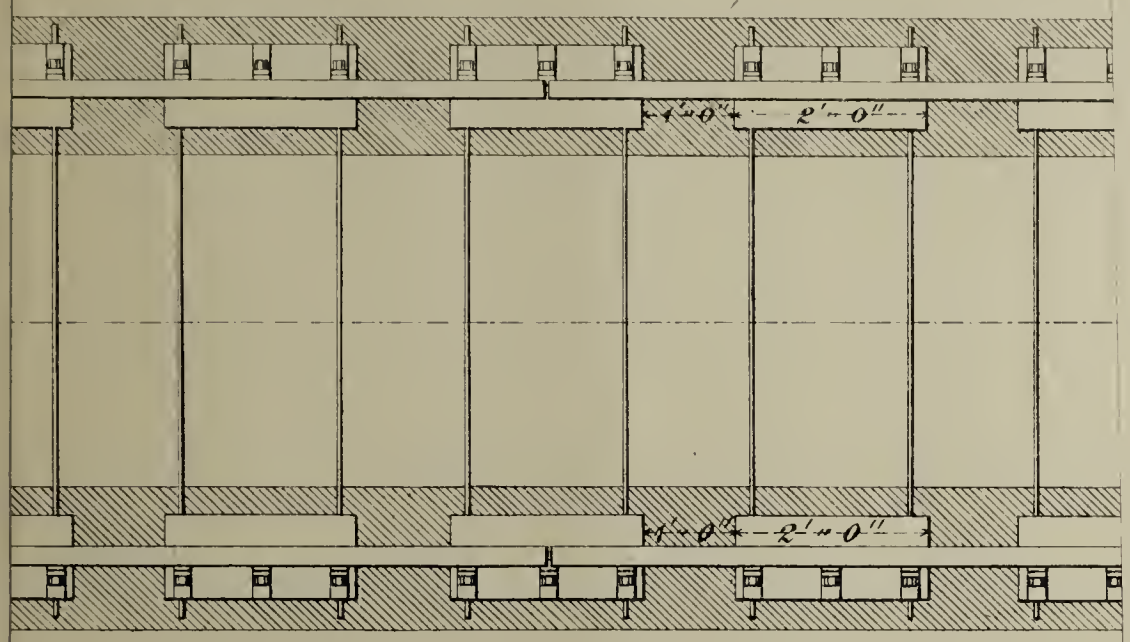


Fig. 14. Longitudinal Elevation on

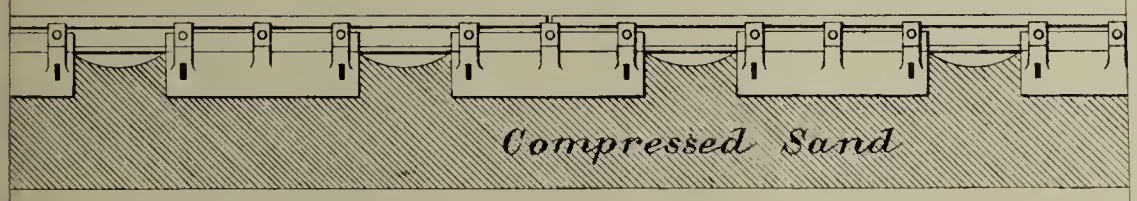
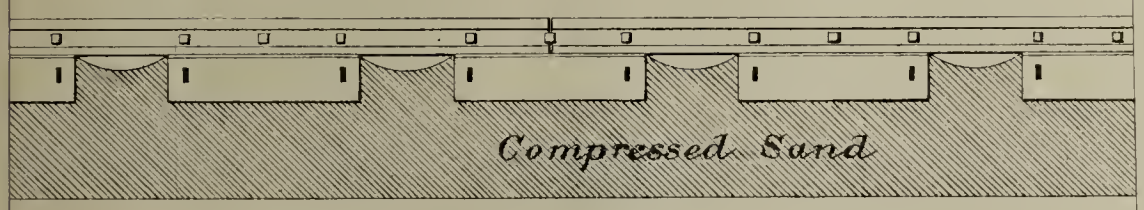


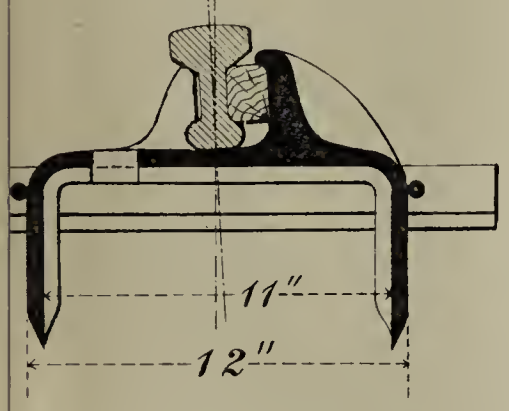
Fig. 15. Longitudinal Section through A



Modifications in the Trough with ordinary Keys & Fish-plates.

Fig. 16

Fig. 17.



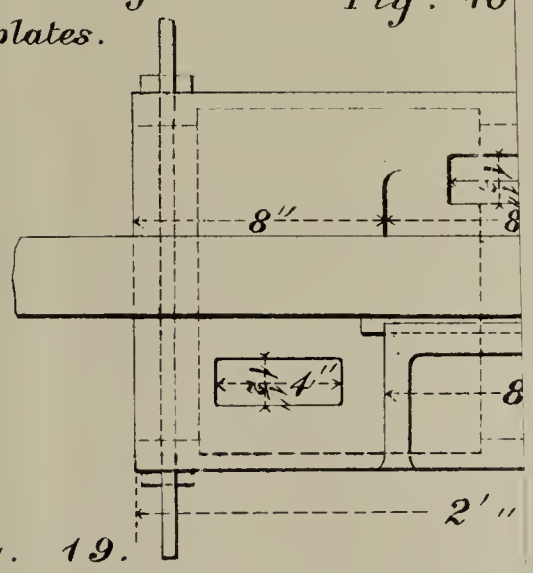


Fig. 19.

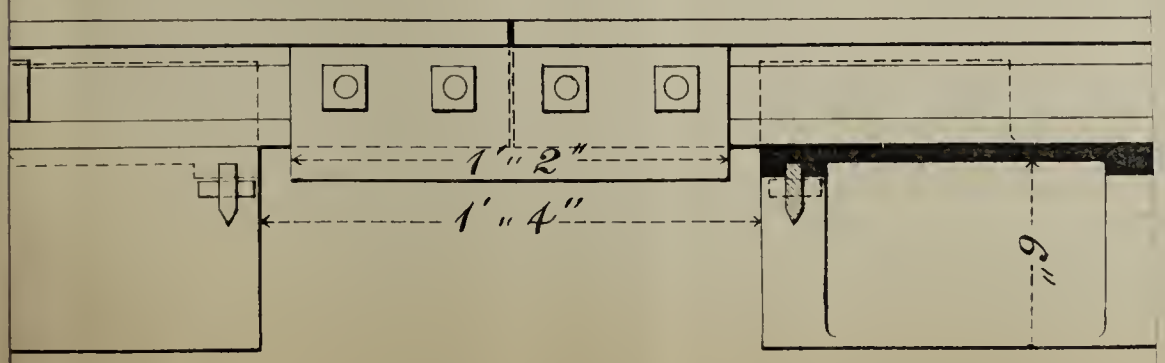
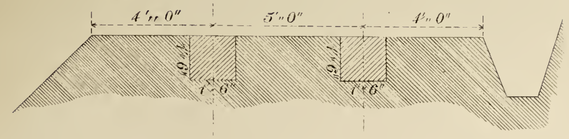


Fig. 1. Section of a single rail.



IRON SLEEPER.

Fig. 2. Cross Section.

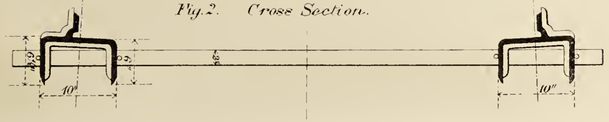


Fig. 3. Plan.

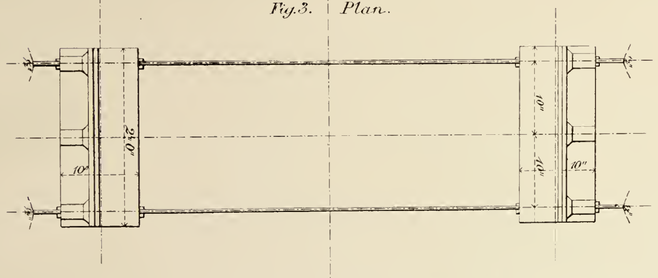


Fig. 4 Longitudinal Section.

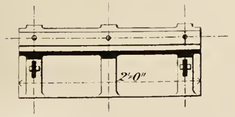


Fig. 5. Side Elevation.

Fig. 6. Cross Section.
The Iron Sleeper embedded in Sand.

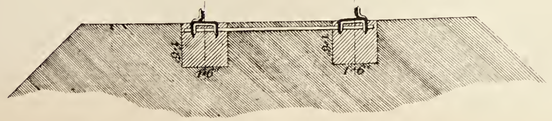


Fig. 7. Railway Formation.
The Iron Sleeper embedded in Ballast.
Plan.

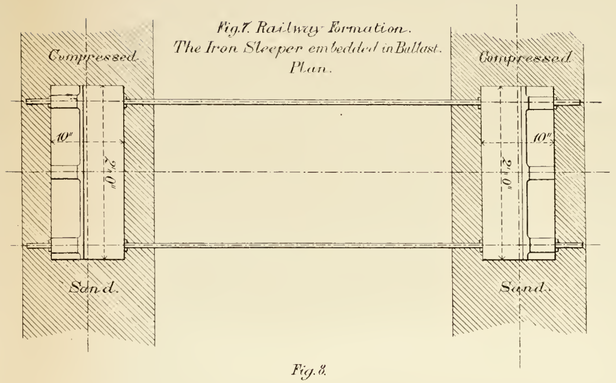


Fig. 8.

Rails 15ft. to 30ft. Long. Lengths multiples of 3ft.

Fig. 9.

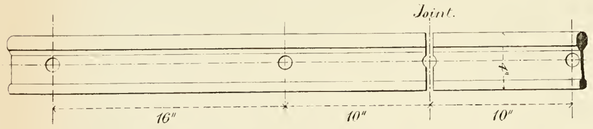


Fig. 10. Rail for Curves.

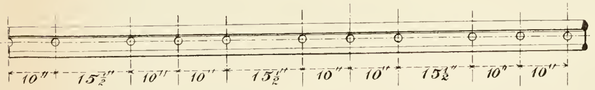


Fig. 11. Section with Bull-headed Rail

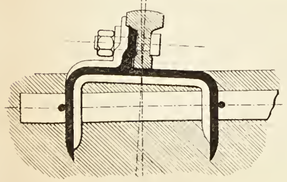


Fig. 12. Section with Vignoles Rail.

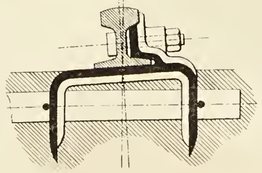


Fig. 13. Plan of Permanent Way.

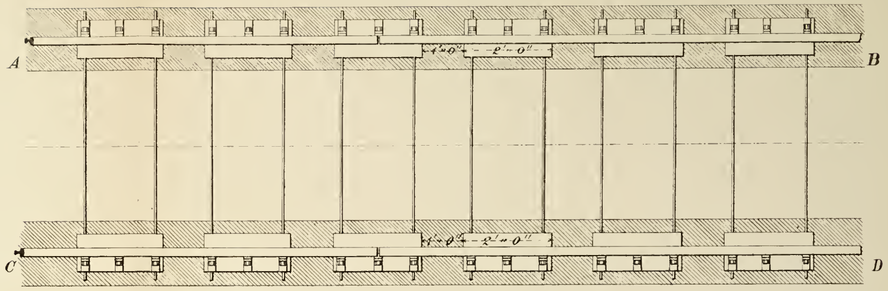


Fig. 14. Longitudinal Elevation on C D.

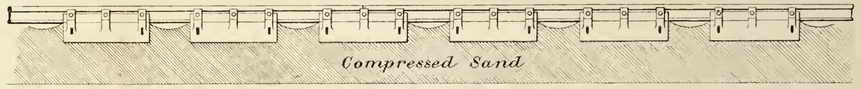


Fig. 15. Longitudinal Section through A B.

Modifications in the Trough with ordinary Keys & Fish-plates.

Fig. 18.

Fig. 17.

Fig. 16.

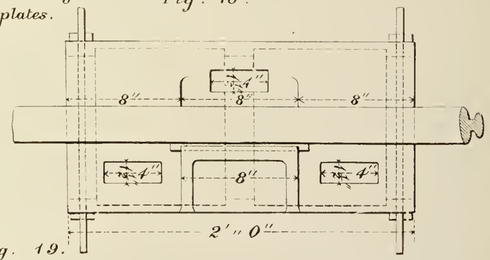
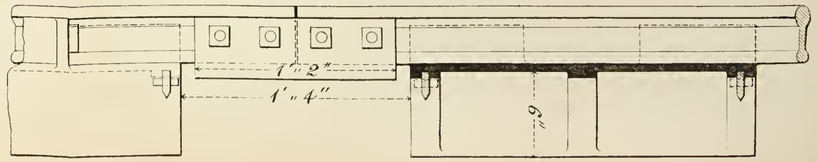


Fig. 19.



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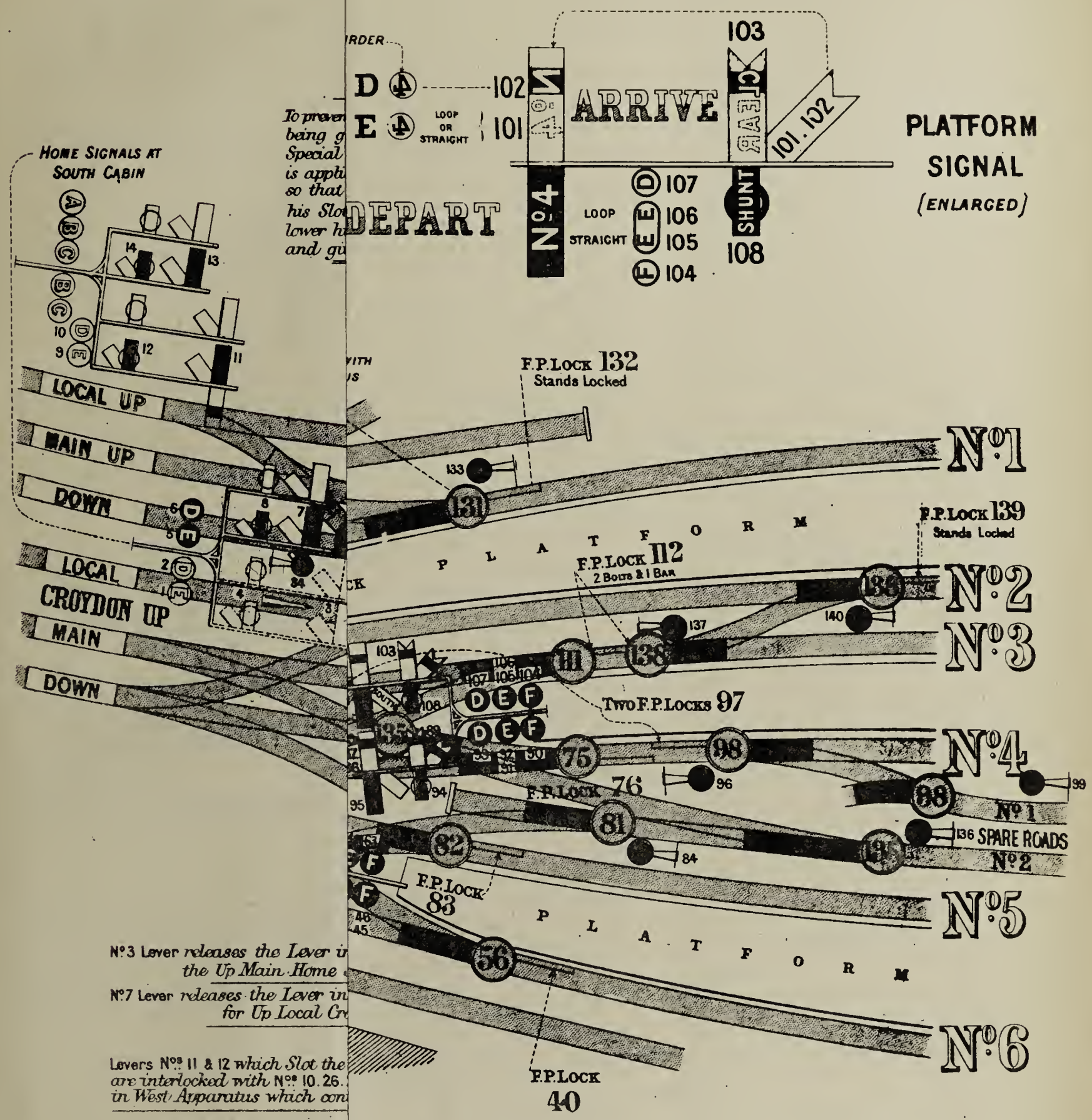


No 3 Lever *releases the Lever in the Up Main Home*

No 7 Lever *releases the Lever in for Up Local Cr*

Levers Nos 11 & 12 *which Slot the are interlocked with* Nos 10. 26. *in West Apparatus which con*

Levers Nos 13 & 14 *which Slot t are interlocked with* Nos 10. 26. 87. 88. 89. 90 *in West Apparatu for lines* A. B. C.

Levers Nos 23. 26. 29. 31 *which London Line are interlocked in West Apparatus, controllin* Nos 108. 111. 114 & 117 *controllin*

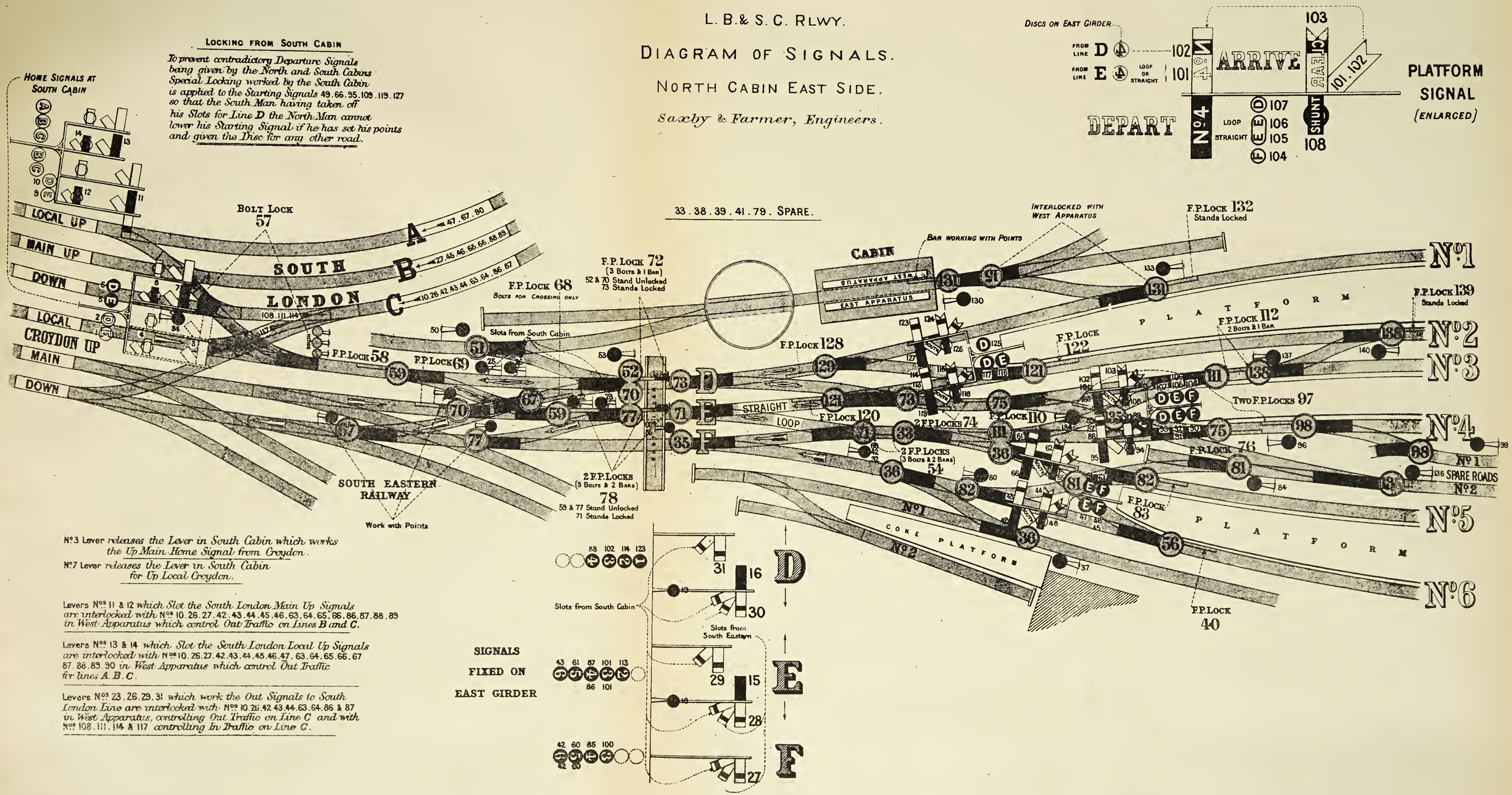
LONDON BRIDGE TERMINUS.

L. B. & S. C. RLWY.

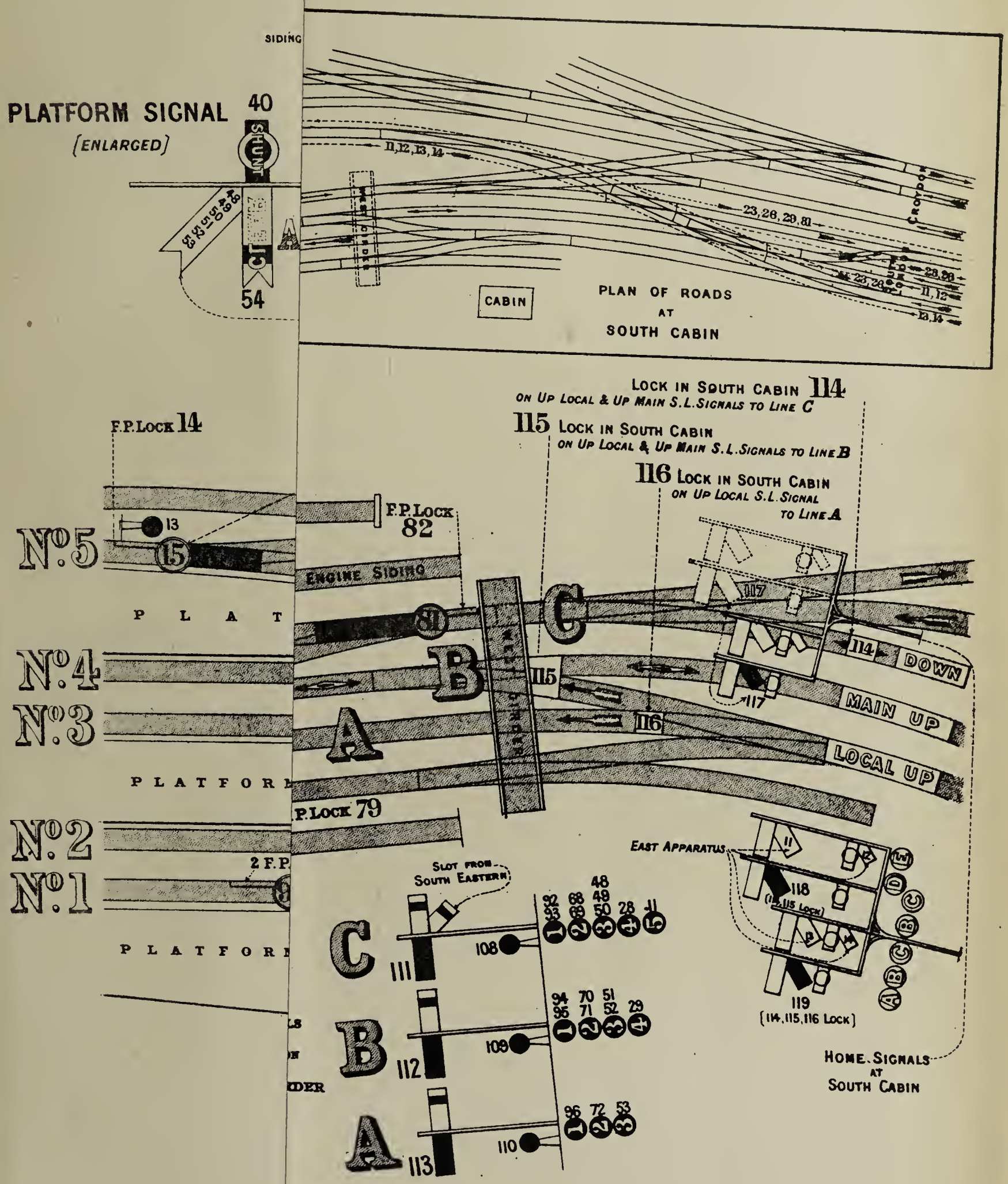
DIAGRAM OF SIGNALS.

NORTH CABIN EAST SIDE.

Saxby & Farmer, Engineers.



THE RAILWAY PRINTING & PUBLISHING COMPANY, 12, CRANE COURT, FLEET STREET, E.C.


SIDING
PLATFORM SIGNAL
(ENLARGED)
40
SHUNT
54
11,12,13,14
23,26,29,31
CROYDON
CABIN
PLAN OF ROADS
AT
SOUTH CABIN
LOCK IN SOUTH CABIN 114
ON UP LOCAL & UP MAIN S.L. SIGNALS TO LINE C
115 LOCK IN SOUTH CABIN
ON UP LOCAL & UP MAIN S.L. SIGNALS TO LINE B
116 LOCK IN SOUTH CABIN
ON UP LOCAL S.L. SIGNAL
TO LINE A
F.P. LOCK 14
F.P. LOCK
82
ENGINE SIDING
No. 5
No. 4
No. 3
No. 2
No. 1
PLAT
PLATFORM
PLATFORM
2 F.P.
P.LOCK 79
DOWN
MAIN UP
LOCAL UP
EAST APPARATUS
118
(114,115 LOCK)
119
(114,115,116 LOCK)
HOME SIGNALS
AT
SOUTH CABIN
SLOT FROM
SOUTH EASTERN
C
B
A
111
112
113
108
109
110

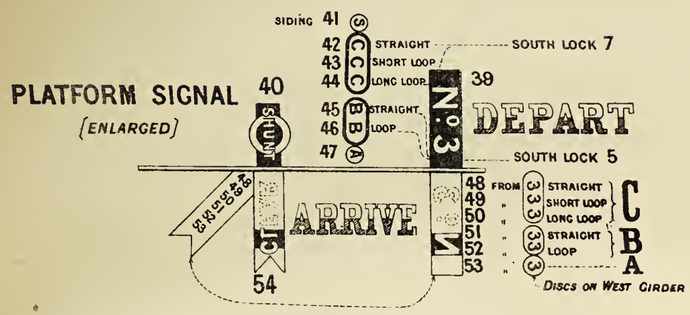
LONDON BRIDGE TERMINUS.

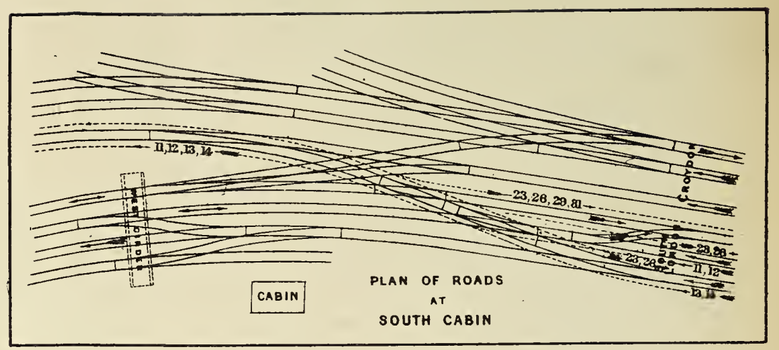
L. B. & S. C. RLWY.

DIAGRAM OF SIGNALS.

NORTH CABIN WEST SIDE.

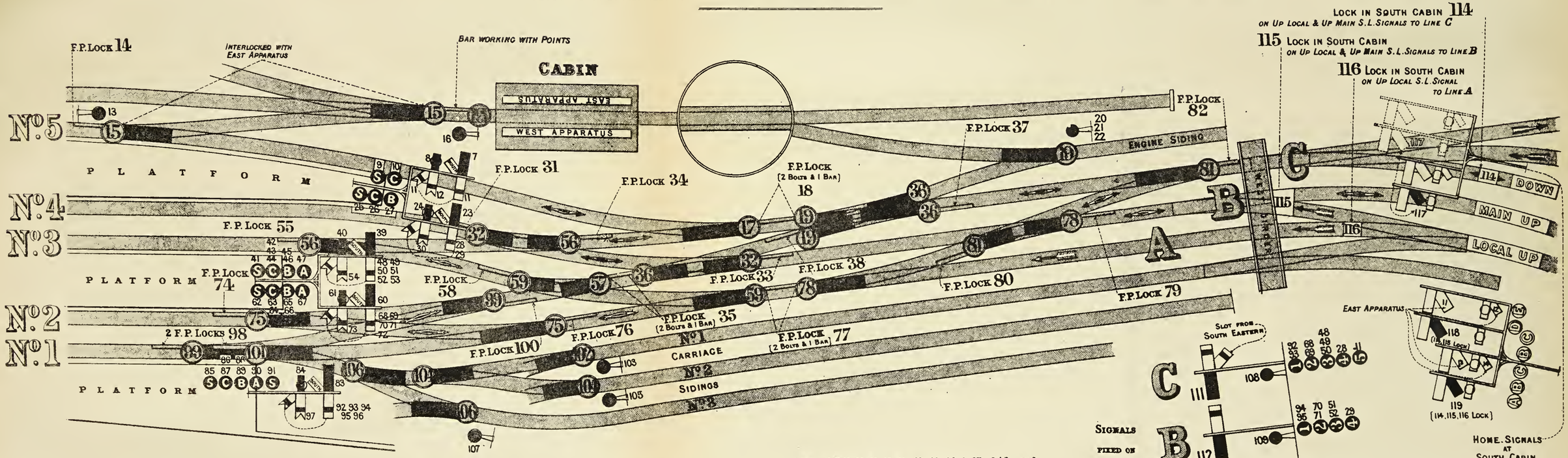
Saxby & Farmer, Engineers.





SPARE LEVERS

1. 2. 3. 4. 5. 6. 120. 121. 122. 123. 124. 125. 126. 127. 128. 129. 130. 131. 132. 133. 134. 135. 136. 137. 138 139. 140.



Levers Nos. 10. 26. 27. 42. 43. 44. 45. 46. 63. 64. 65. 66. 86. 87. 88. 89 *which work the Indicating Discs for Lines* **B** *&* **C** *and release the Starting Signals* Nos. 7. 23. 39. 60. 83 *are interlocked with* Nos. 11. 12. 13 & 14 Levers *in East Apparatus working the Slots on South London Up Main to East Side. (See Key Plan.)*

Levers Nos. 47. 67. 90 *which work the Indicating Discs for Line* **A** *& release the Shunting Signals* Nos. 40. 61. 84 *are interlocked with* Nos. 13 & 14 Levers *in East Apparatus working the Slots on South London Up Local to East Side. (See Key Plan.)*

Levers Nos. 10. 26. 42. 43. 44. 63. 64. 86 & 87 *which work the Indicating Discs for* **C** *and release the Starting Signals for Line* **C** *and* Levers Nos. 108. 111. 114. 117 *which work In Signals for Line* **C** *are interlocked with* Nos. 23. 26. 29. 31 *in East Apparatus working South London Out Signals from East Side. (See Key Plan.)*

23 & 26 *release the East Starting Signals for South London.*

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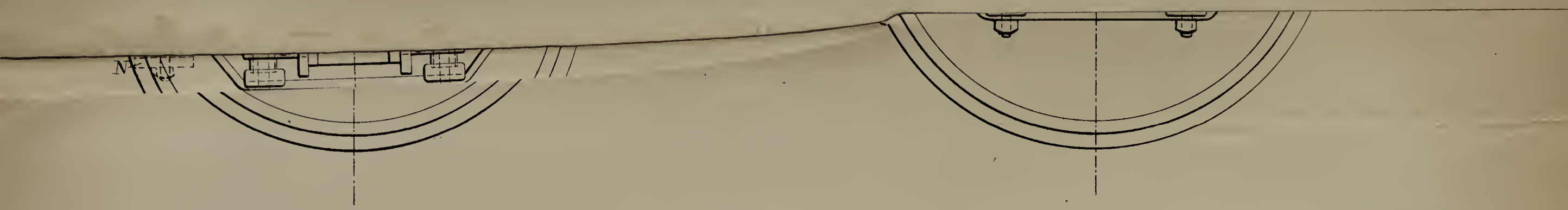


Fig. 5. End View.

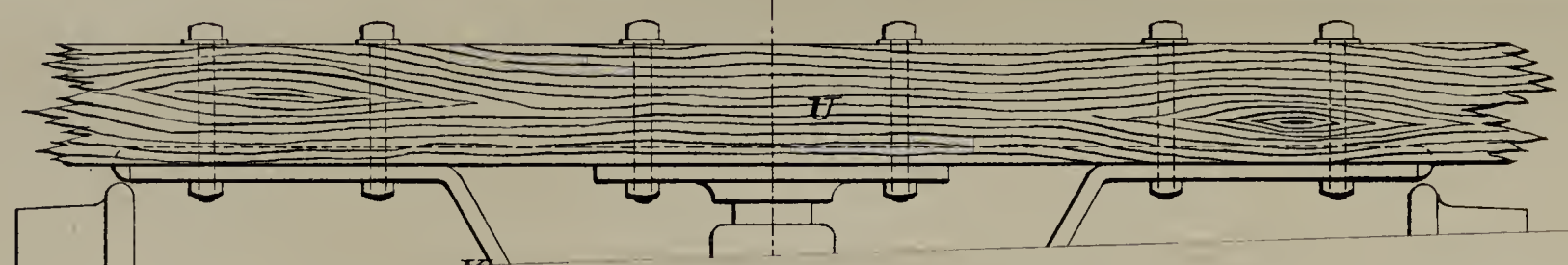


Fig. 1. Plan.

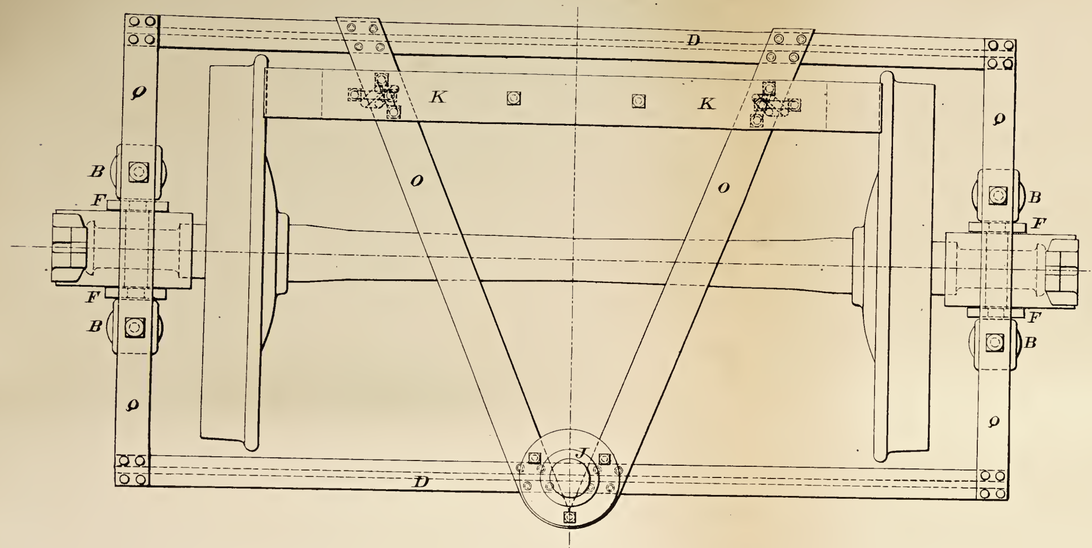


Fig. 2. Side Elevation.

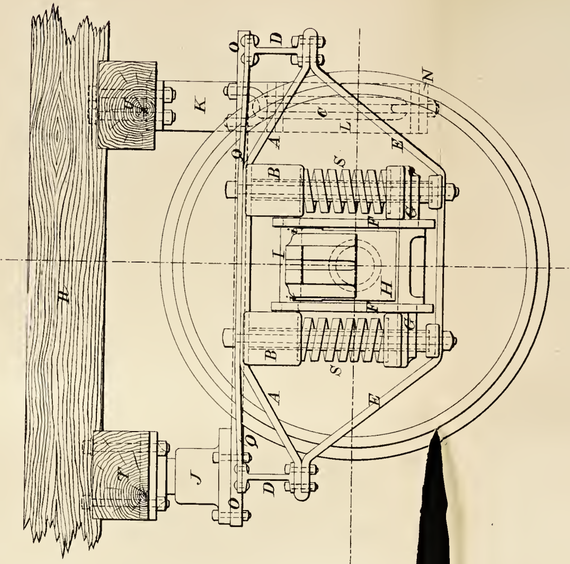


Fig. 3. Plan.

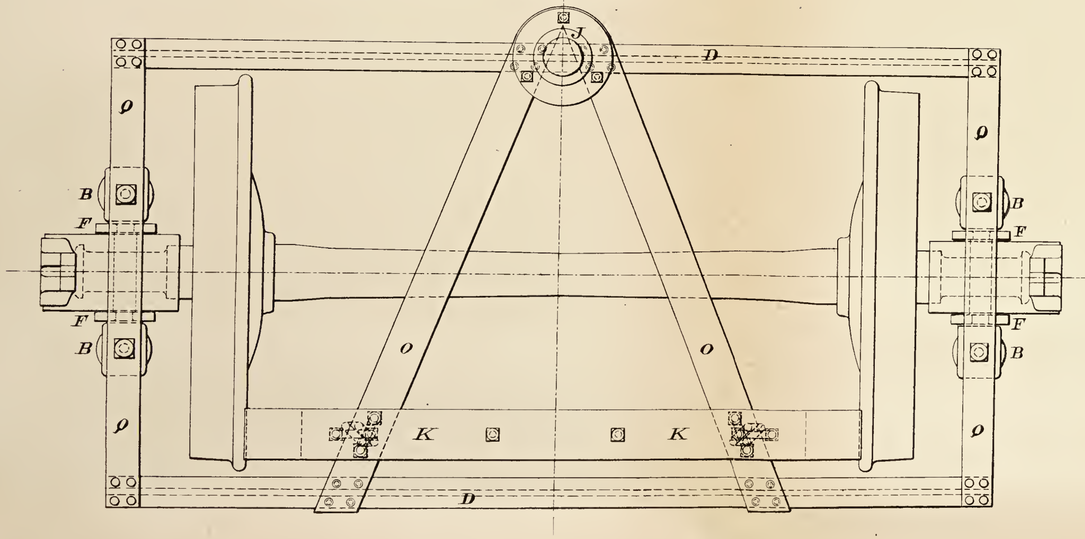


Fig. 4. Side Elevation.

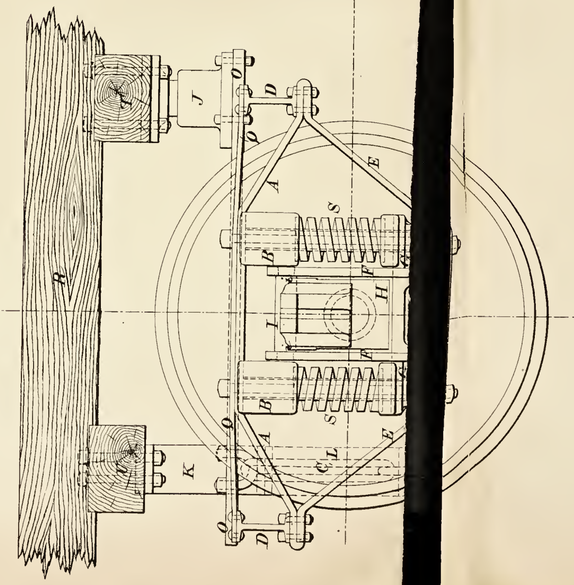
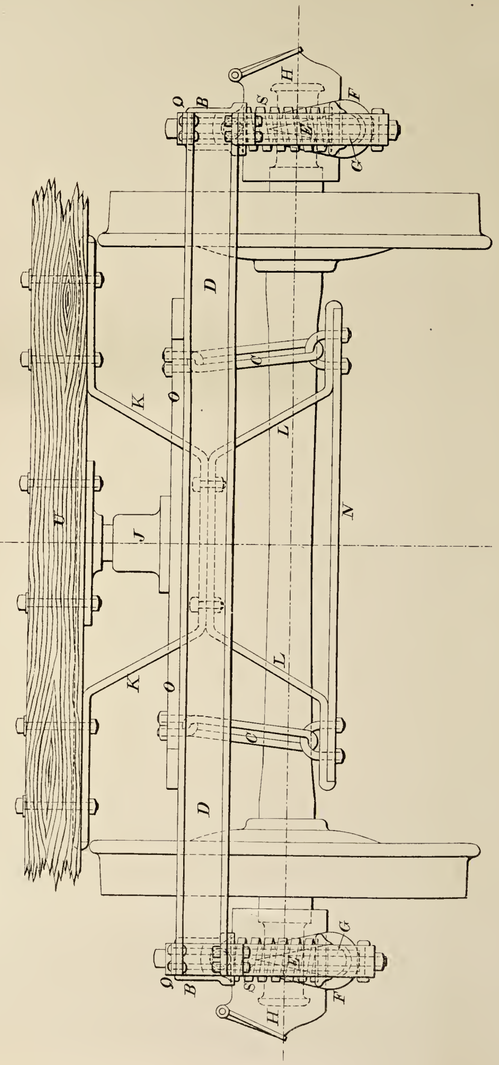


Fig. 5. End View.



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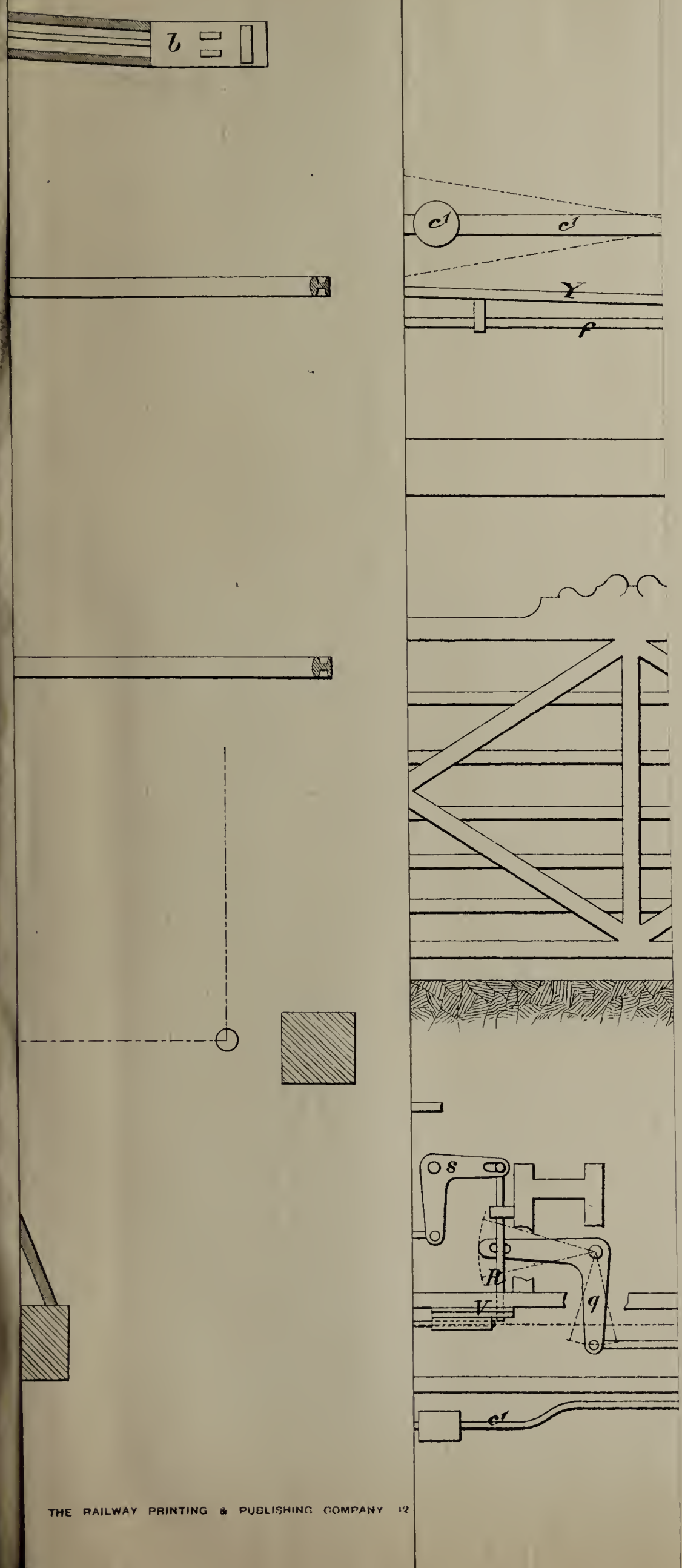


Fig. 263.

Fig. 258.

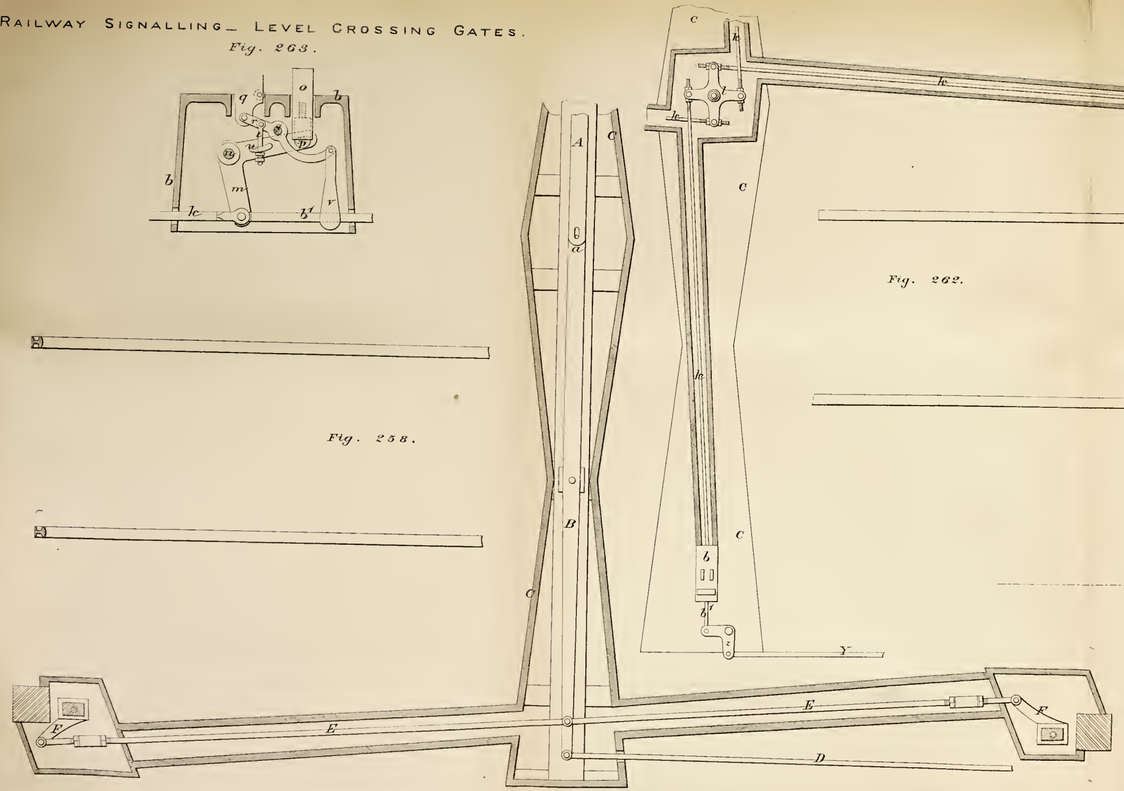
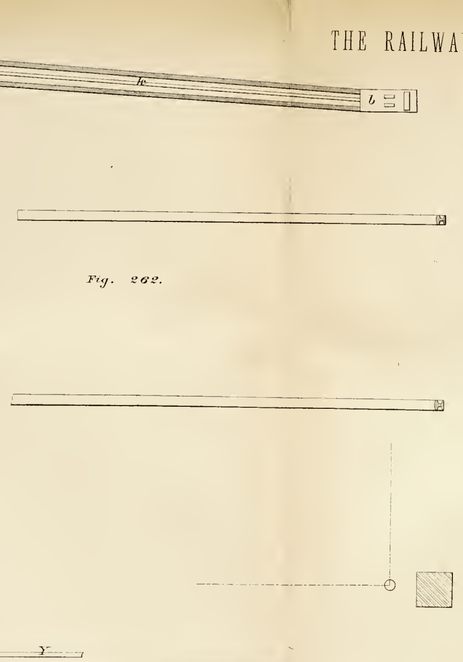


Fig. 262.



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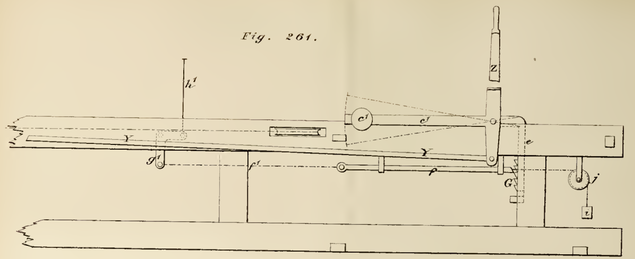

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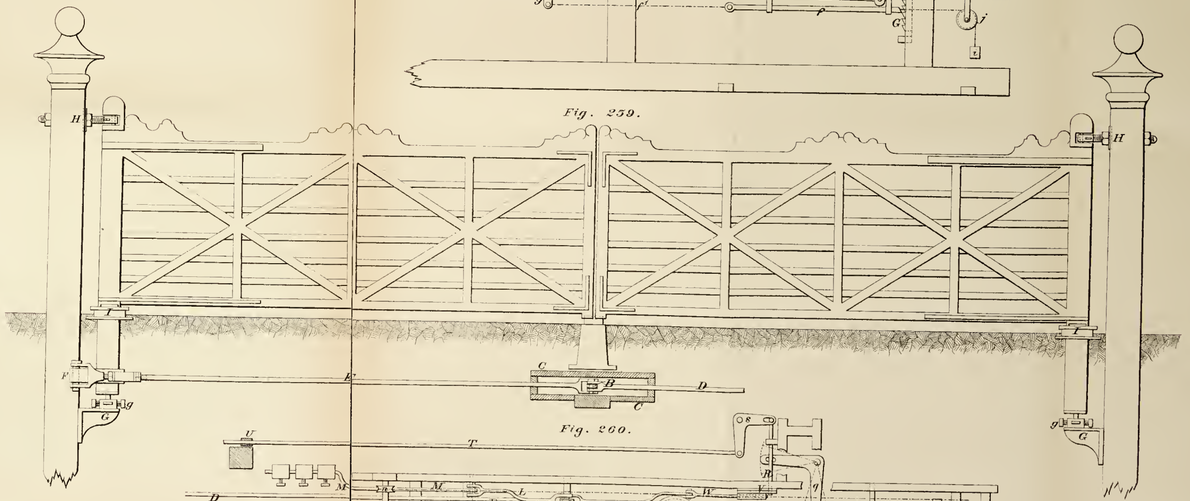

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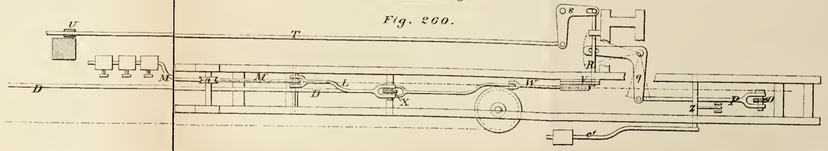

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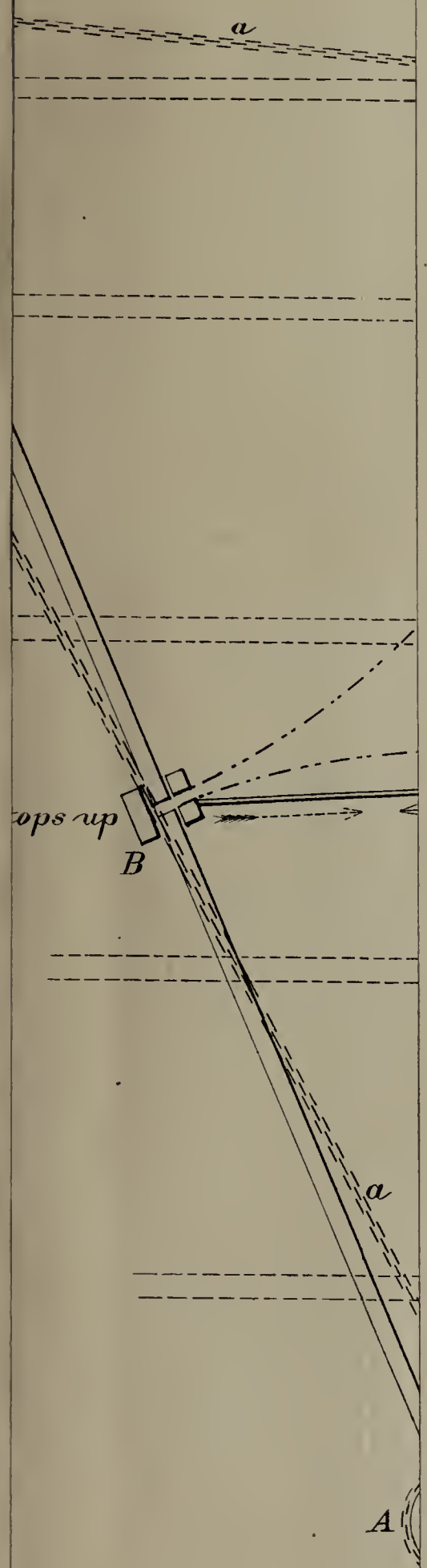

WHITE'S PATENT FOG SIGNALS.

Fig. A.

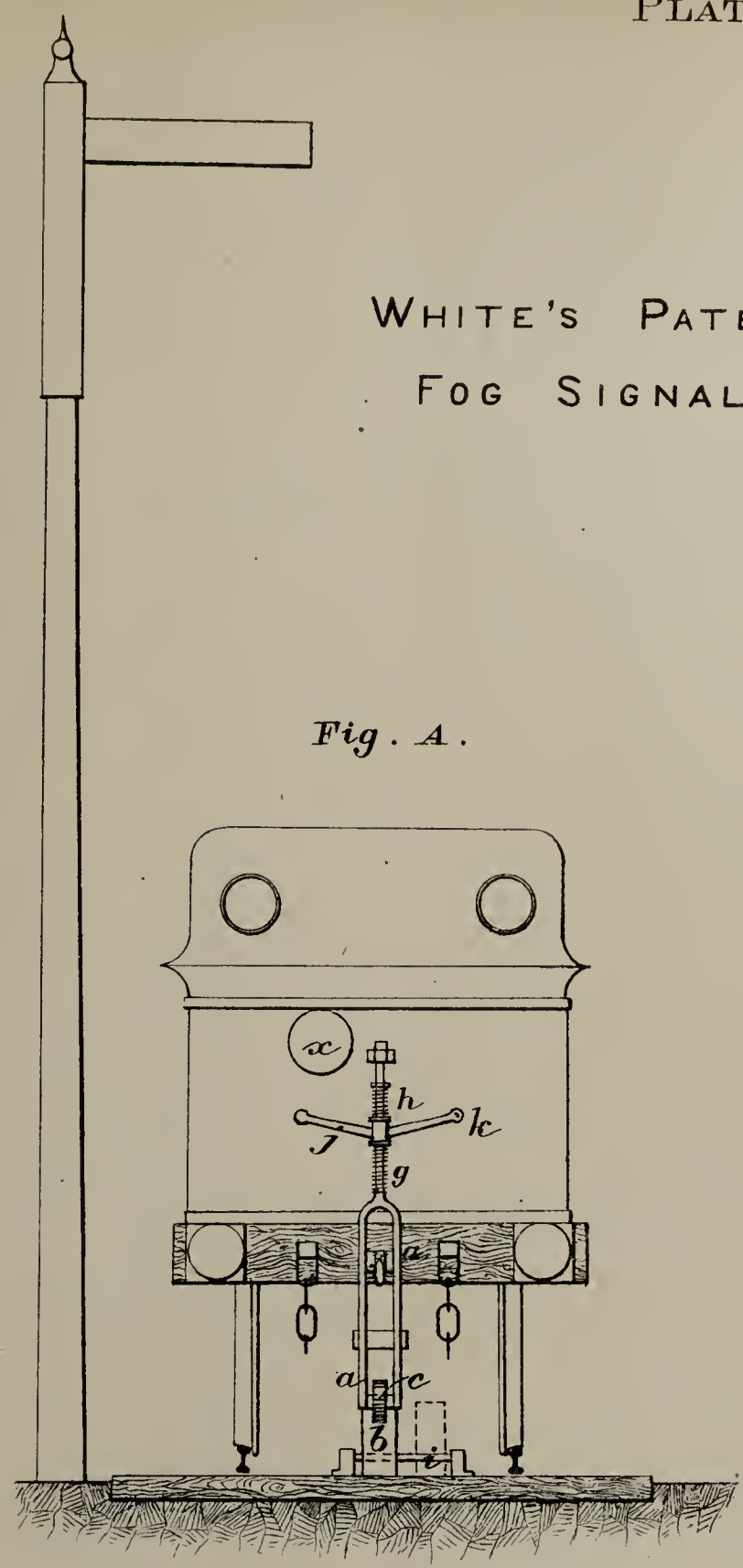

Fig. B.

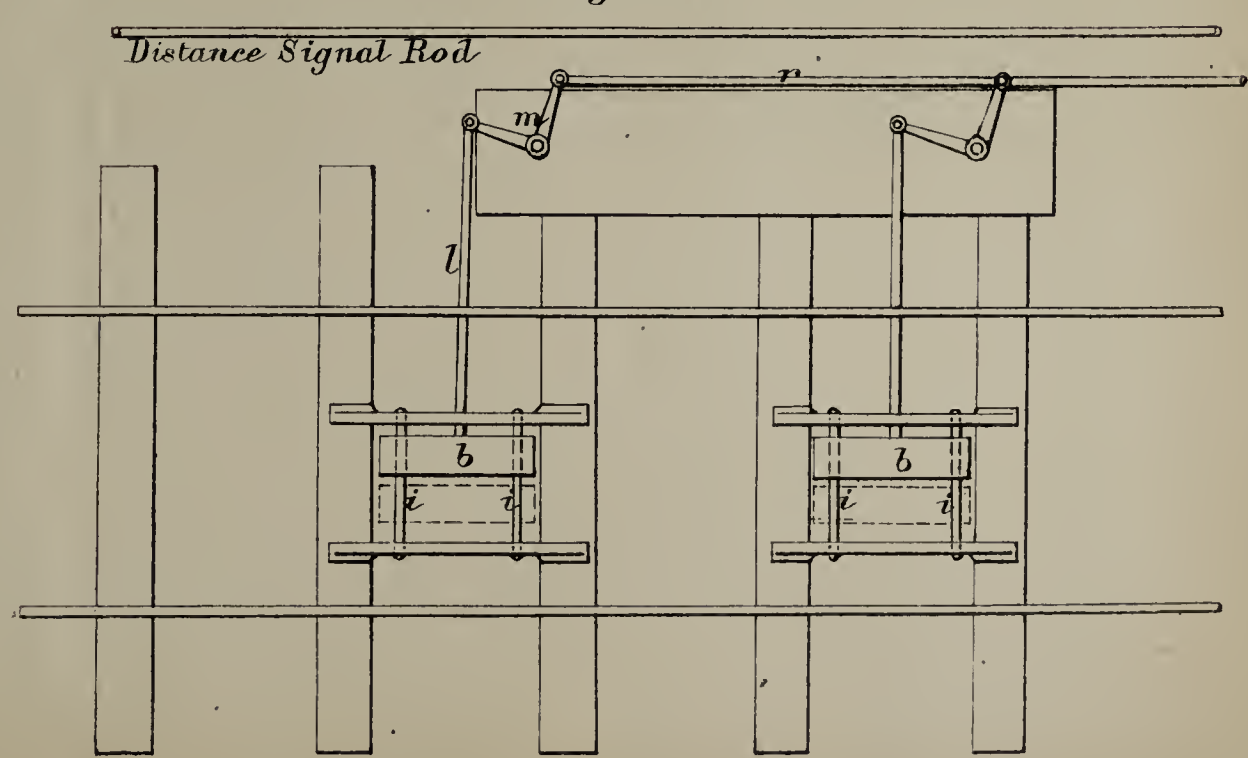

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Fig. 264.

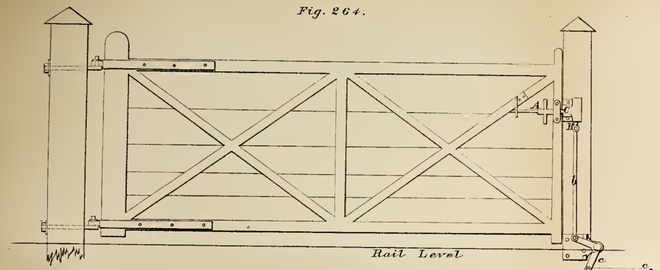


Fig. 266.

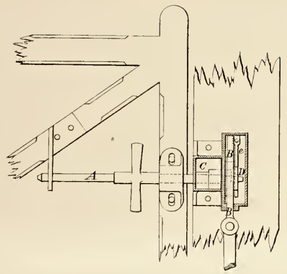
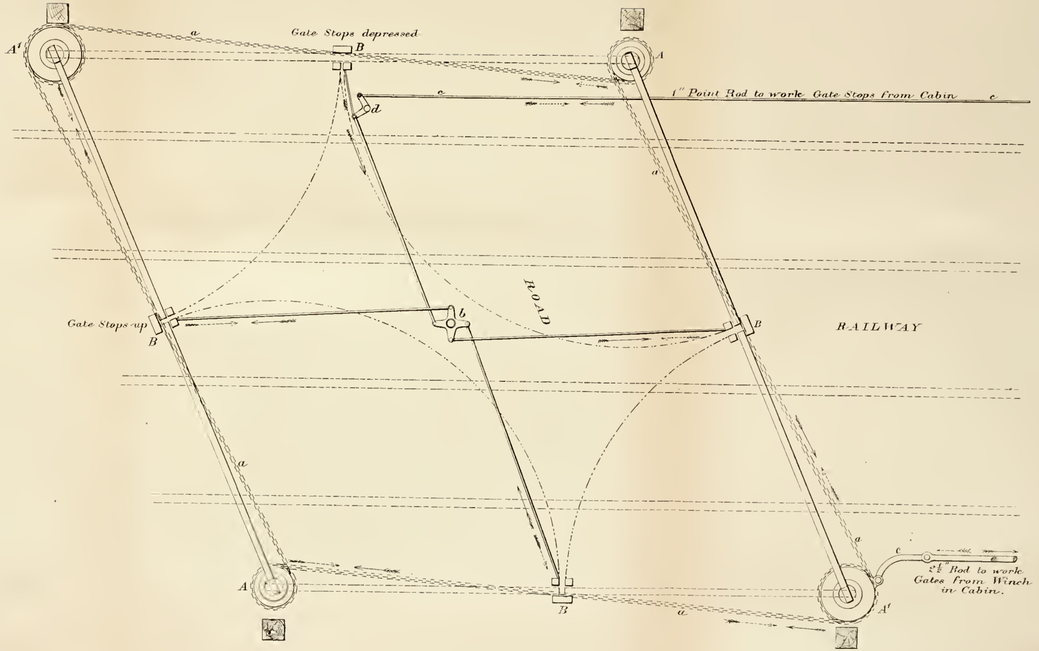


Fig. 265

Fig. 266a.

Fig. 267.



WHITE'S PATENT FOG SIGNALS.

Fig. A.

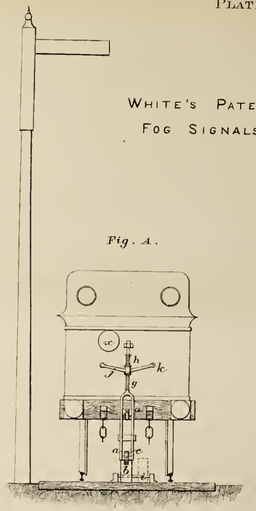


Fig. B.

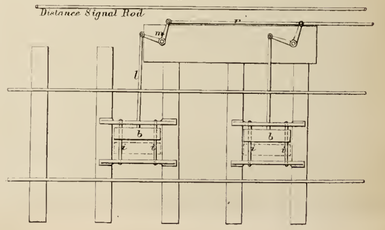


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Fig. 9.

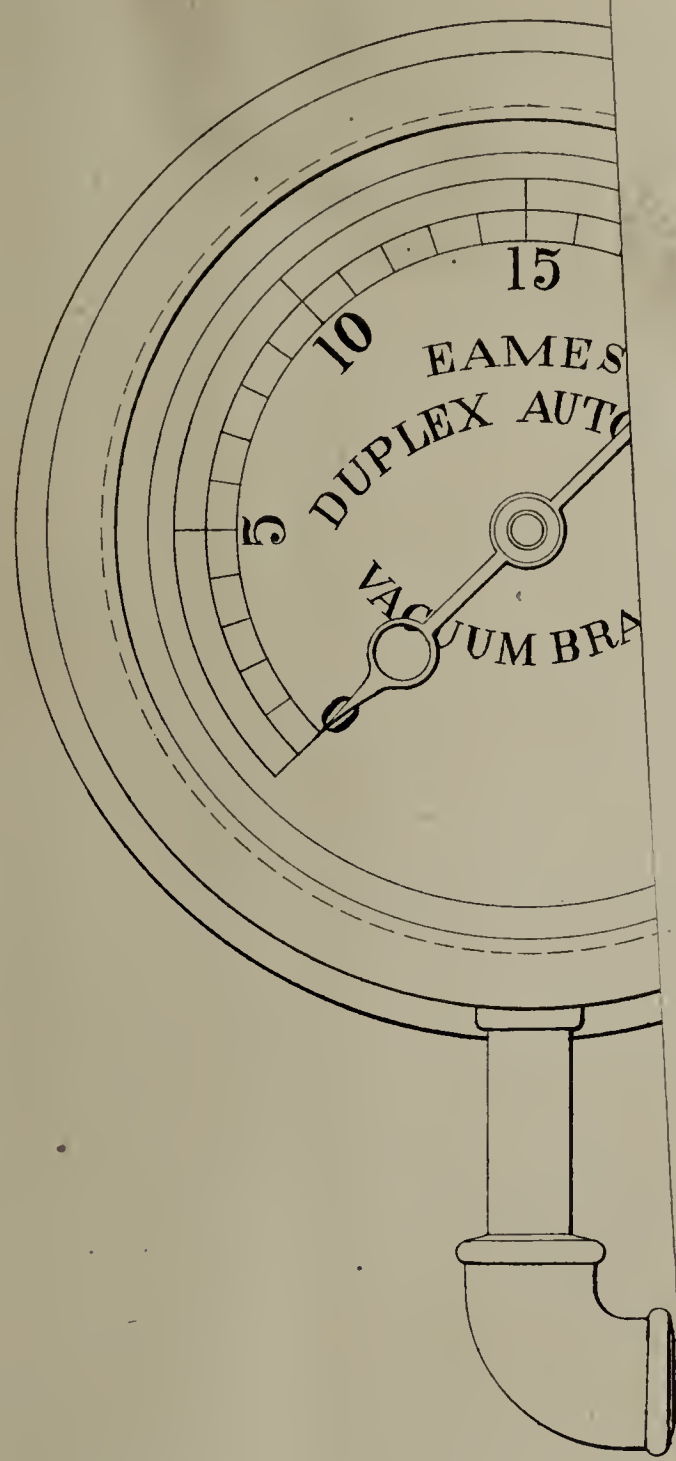
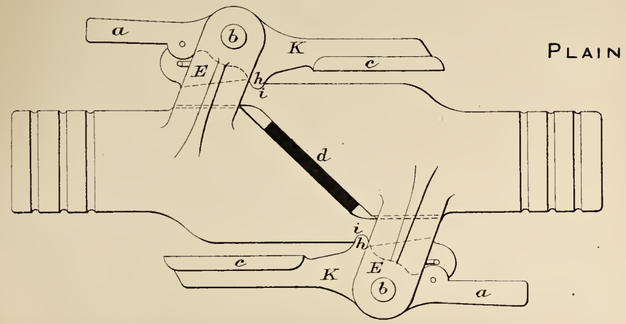


FIG. 3.



PLAIN BRAKE COUPLING

FIG. 1.

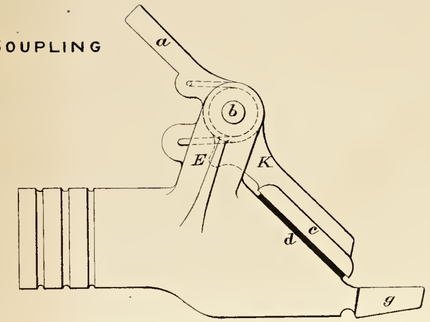


FIG. 2.

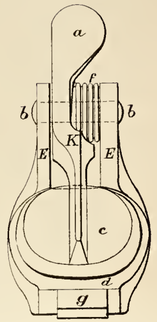


FIG. 9. VACUUM GAUGE.

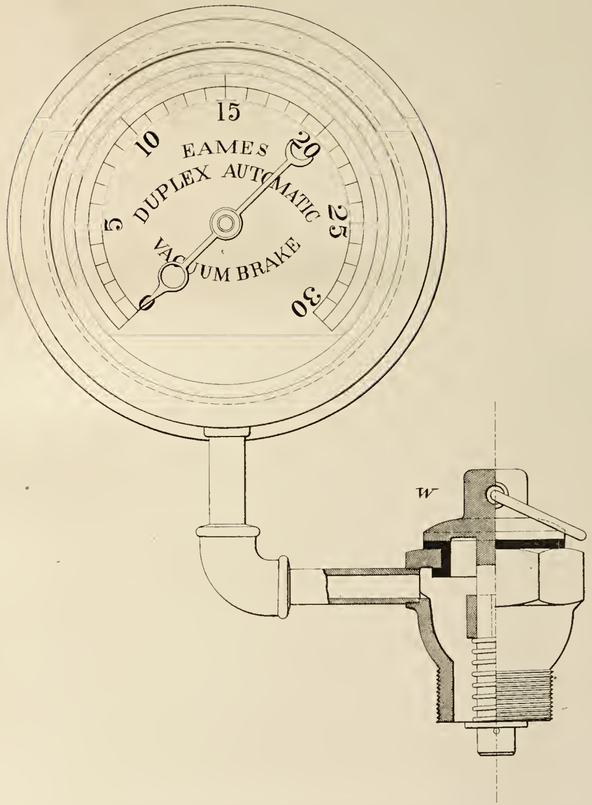
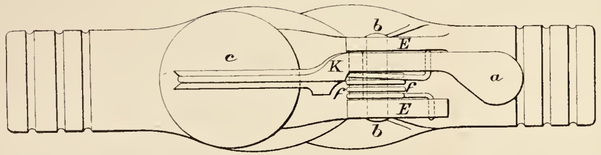


FIG. 4.



AUTOMATIC BRAKE COUPLING

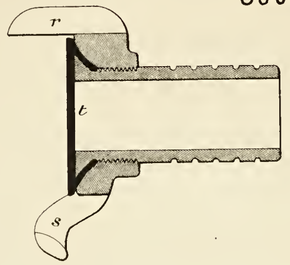


FIG. 6.

FIG. 5.

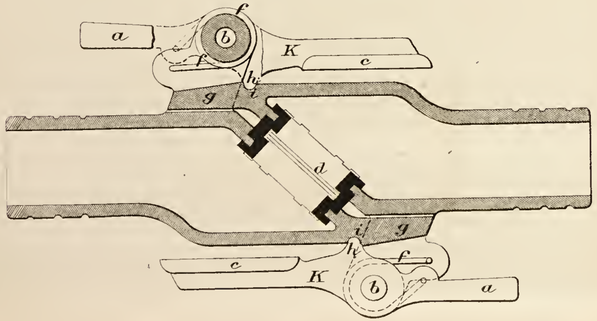


FIG. 8.

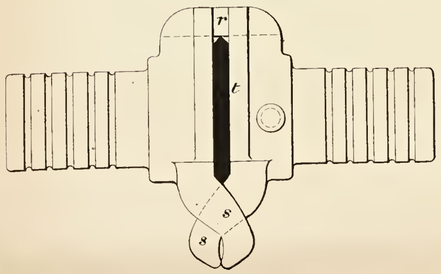
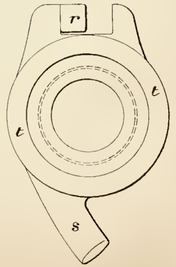


FIG. 7.



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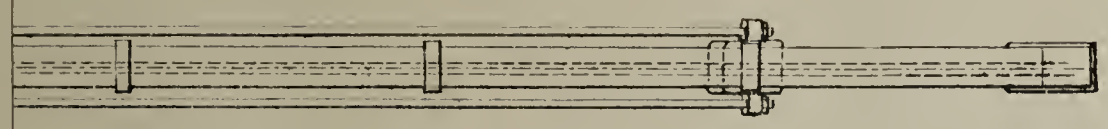
. 277. *Plan.*



278. *Elevation*

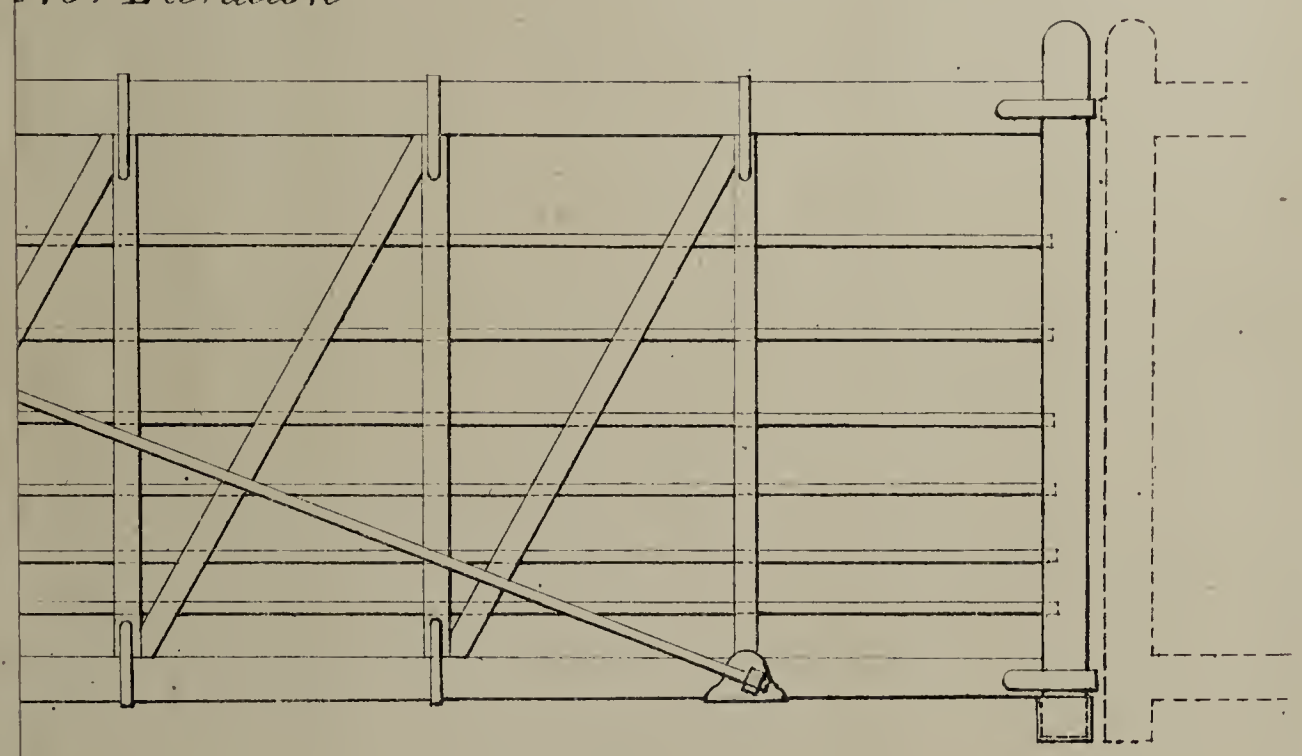
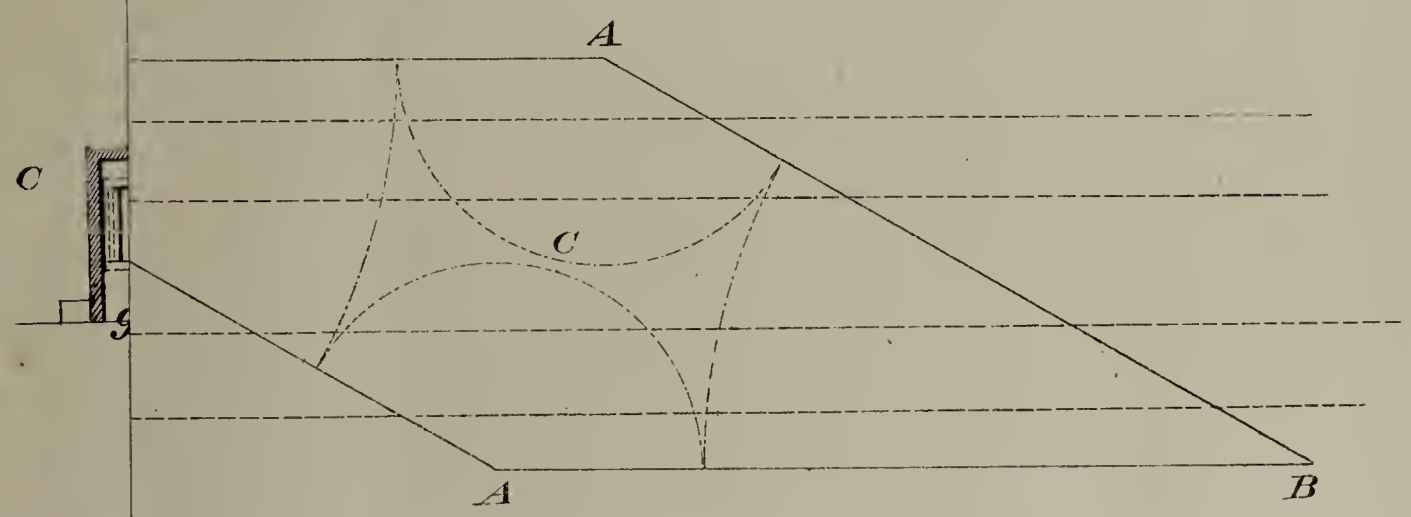


Fig. 269.



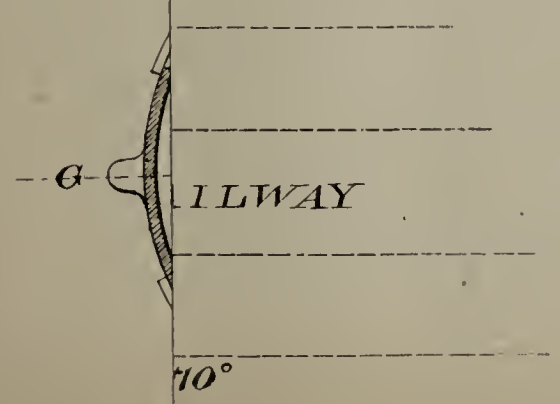


Fig. 270. Key Plan.

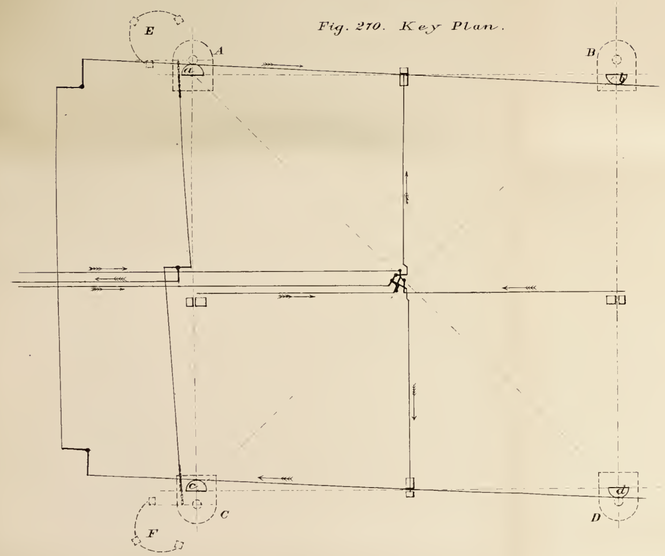


Fig. 271. Elevation.

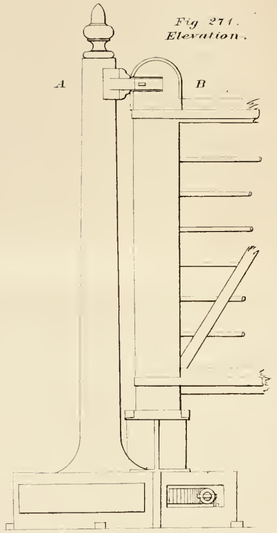


Fig. 273. Section through G H.

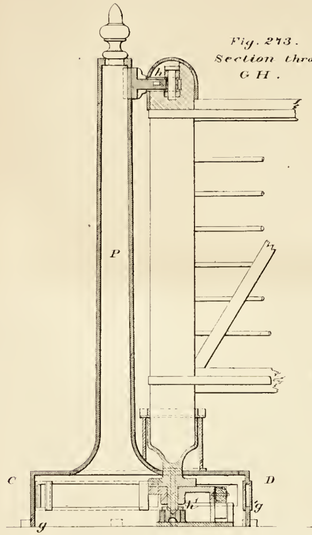


Fig. 275 Section through I J

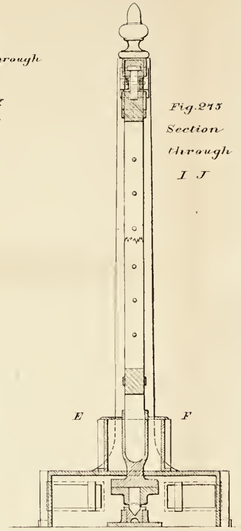


Fig. 276. Section through EF

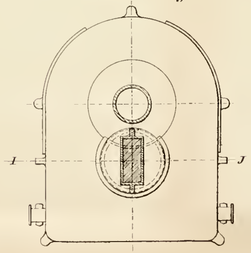


Fig. 272. Section through A B.

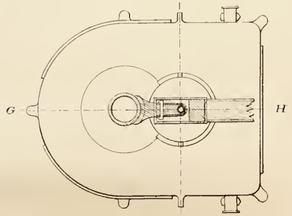


Fig. 274. Section through CD

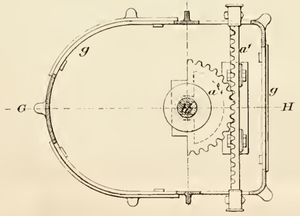


Fig. 277. Plan.

Fig. 278. Elevation

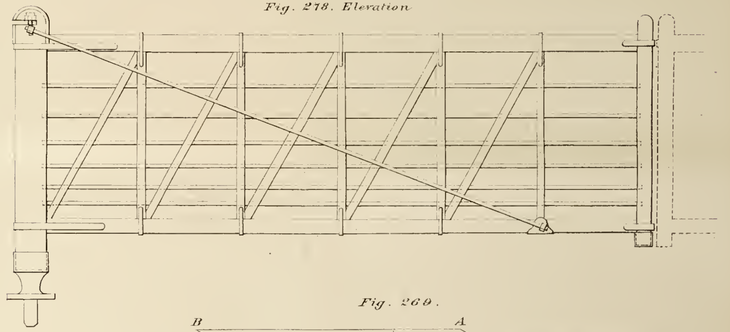
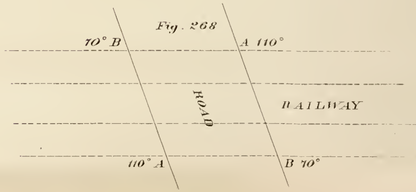


Fig. 269.

Fig. 268



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Wicket Gate.

Fig. 283. Elevation

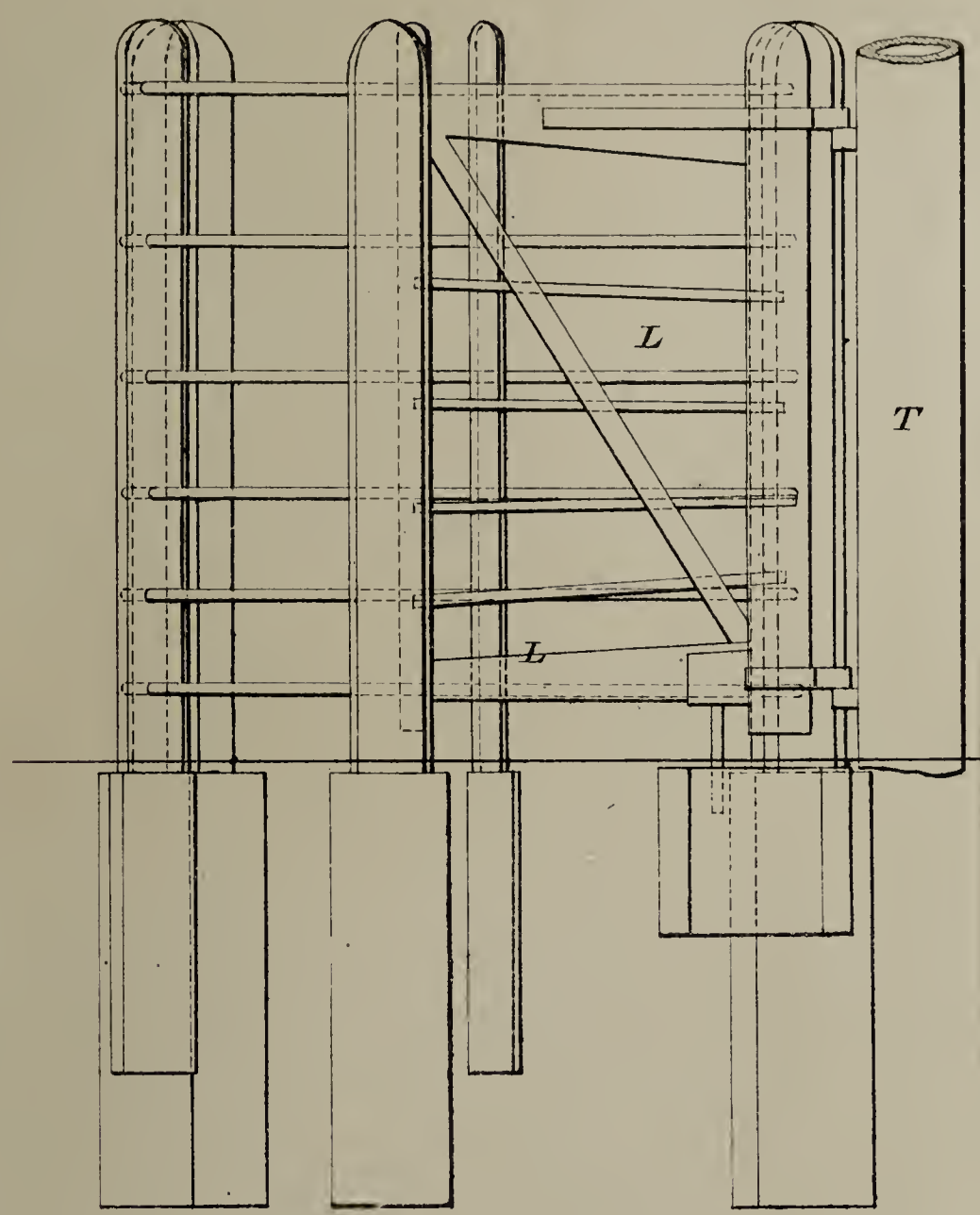
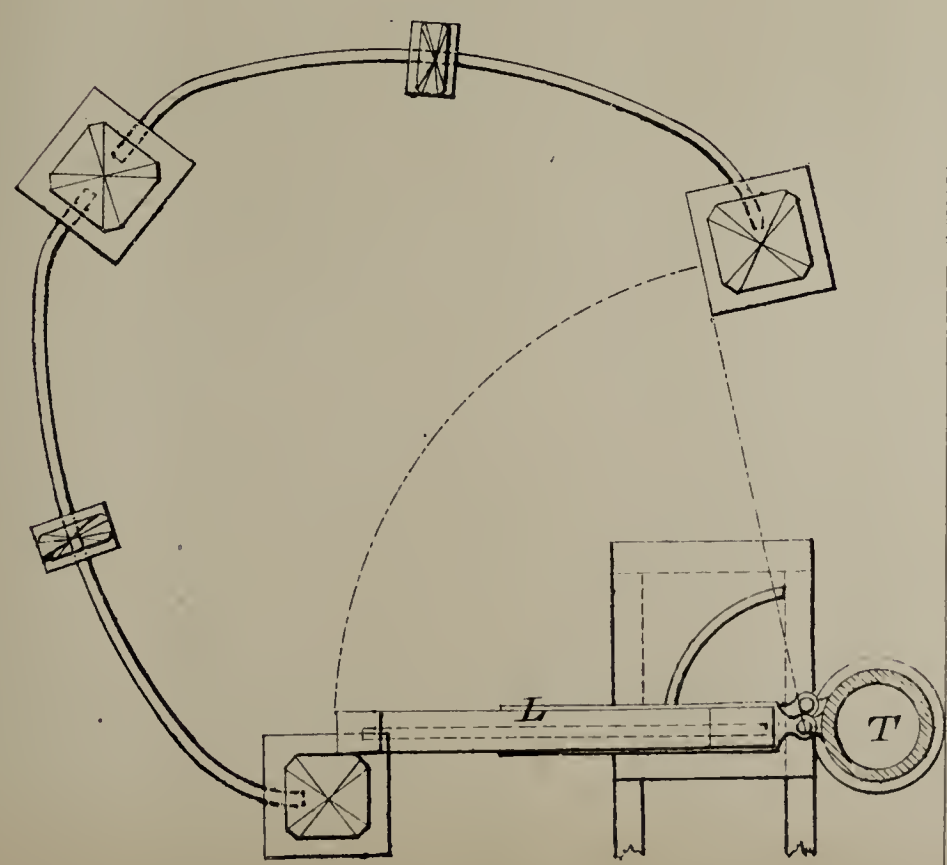


Fig. 284. Plan.



Capstan.

Fig. 279.
End View.

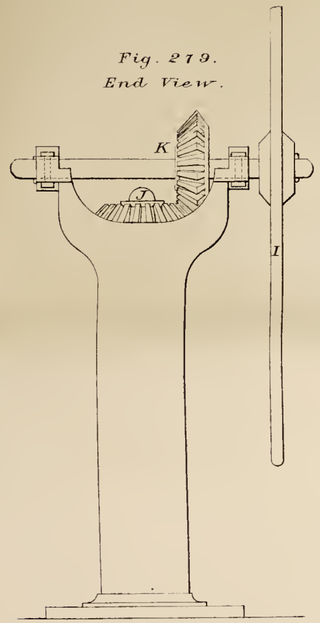


Fig. 280.
Sectional Elevation.

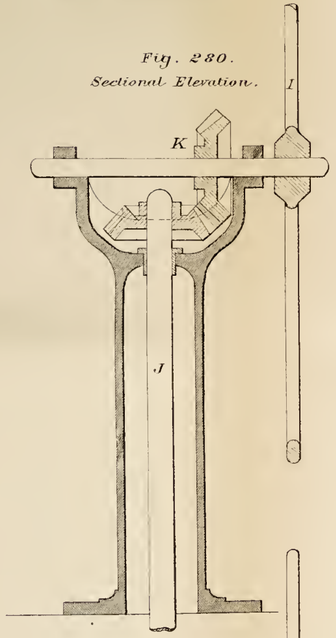


Fig. 281.
Plan.

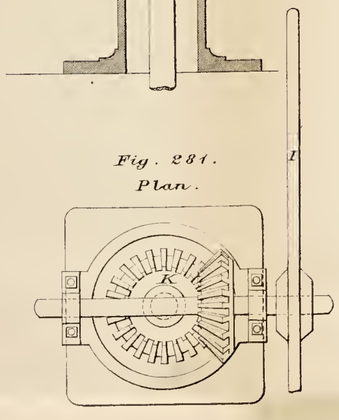
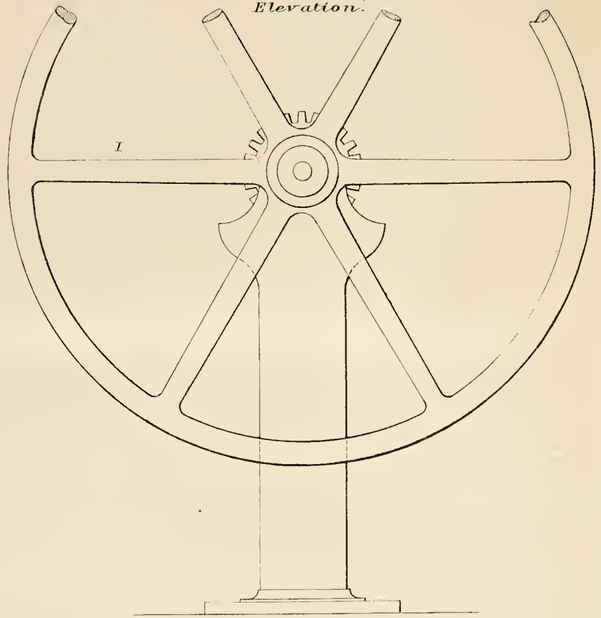


Fig. 282.
Elevation.



W.I. Hinge.
Fig. 285.

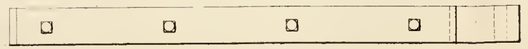


Fig. 286

Wicket Gate.
Fig. 283. Elevation

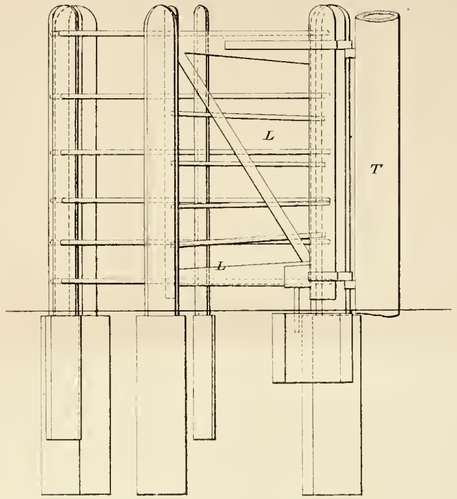


Fig. 284. Plan.

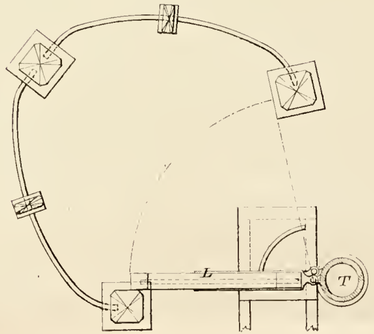
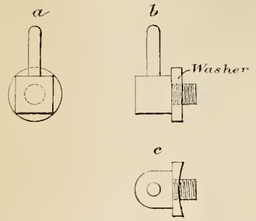
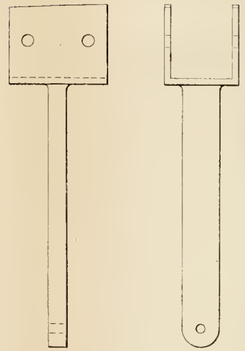


Fig. 287.
W.I. Hanger.



W.I. Shoe.
Fig. 288. Fig. 289.



W.I. Hinge.
Fig. 290.

Fig. 291.

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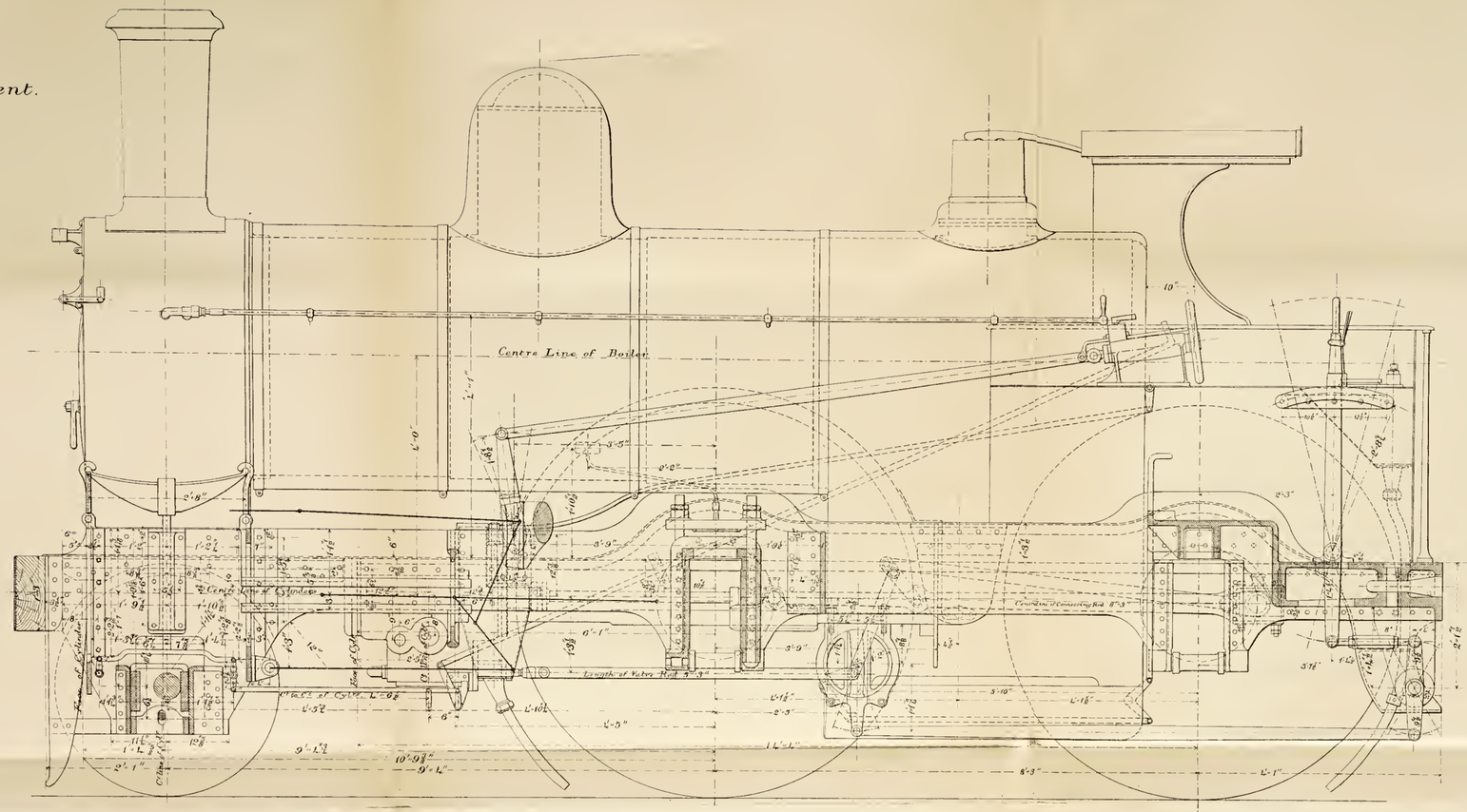
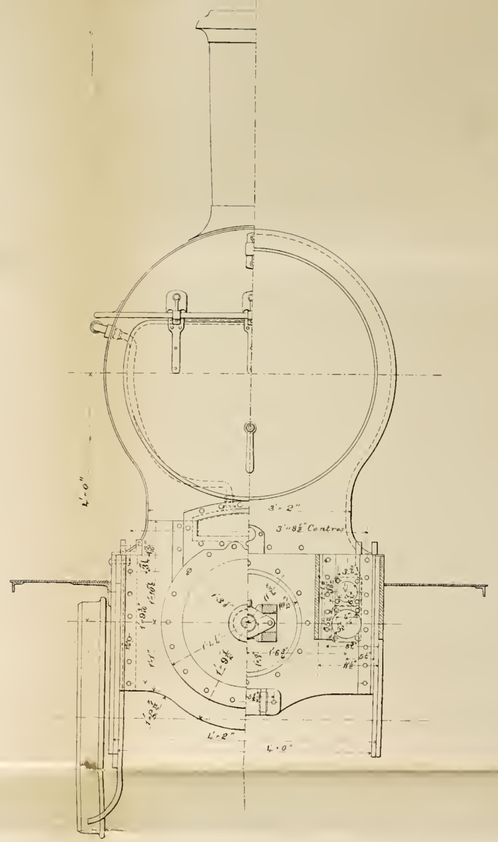
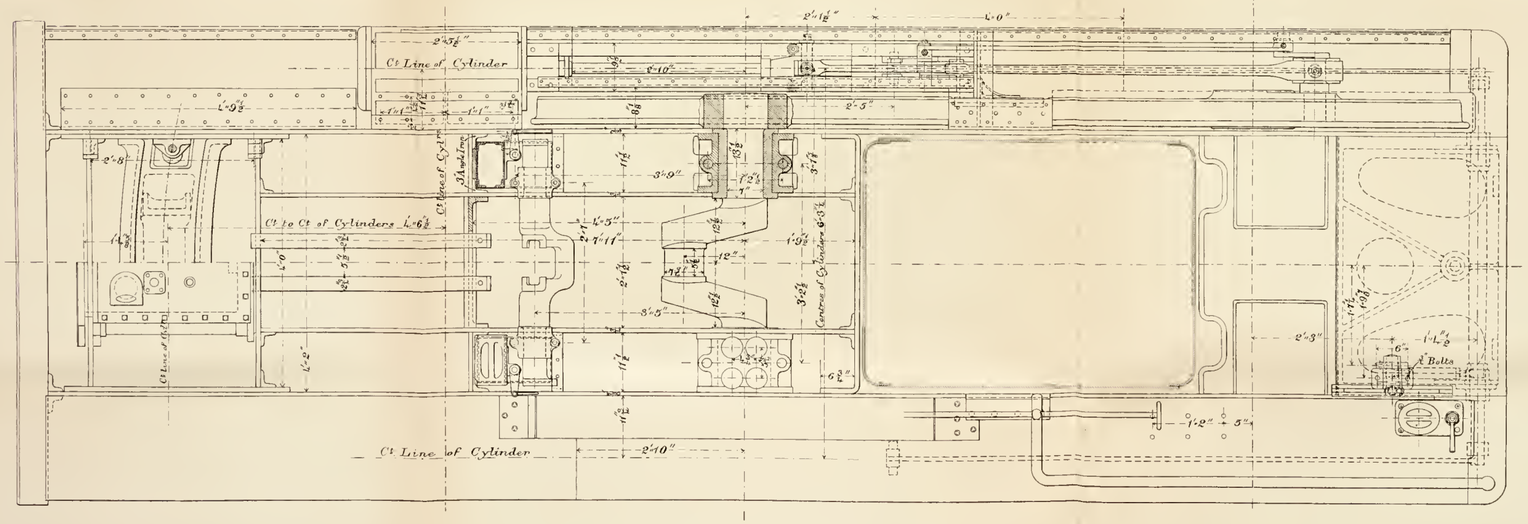
THE RAI

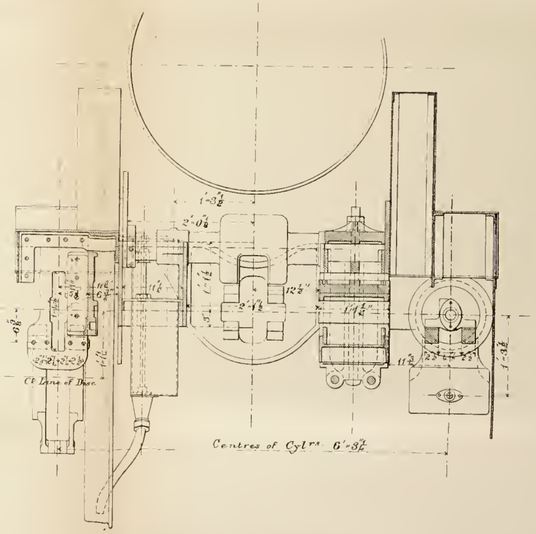
WEBB'S 3-CYLINDER COMPOUND LOCOMOTIVE.

General Arrangement.









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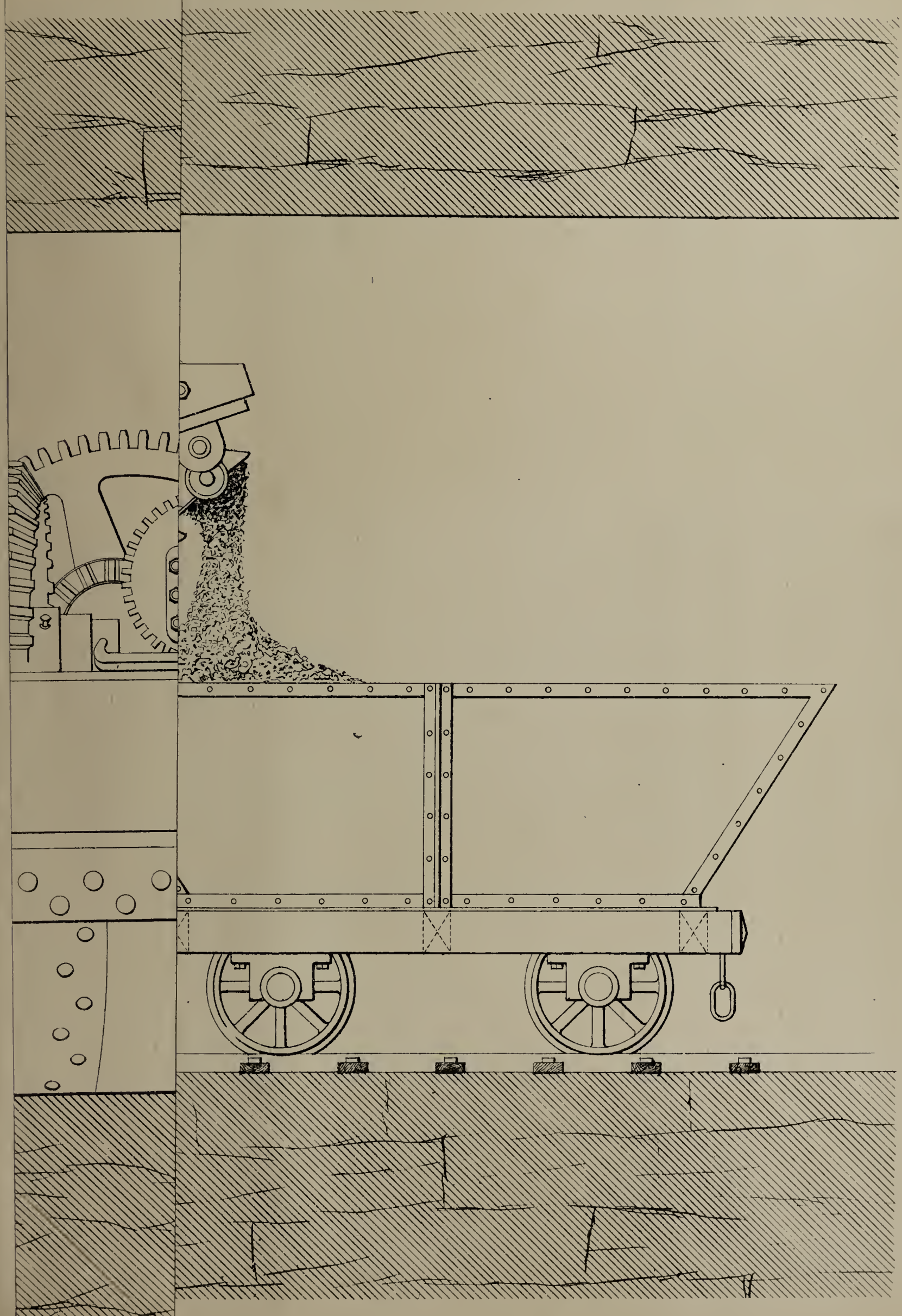

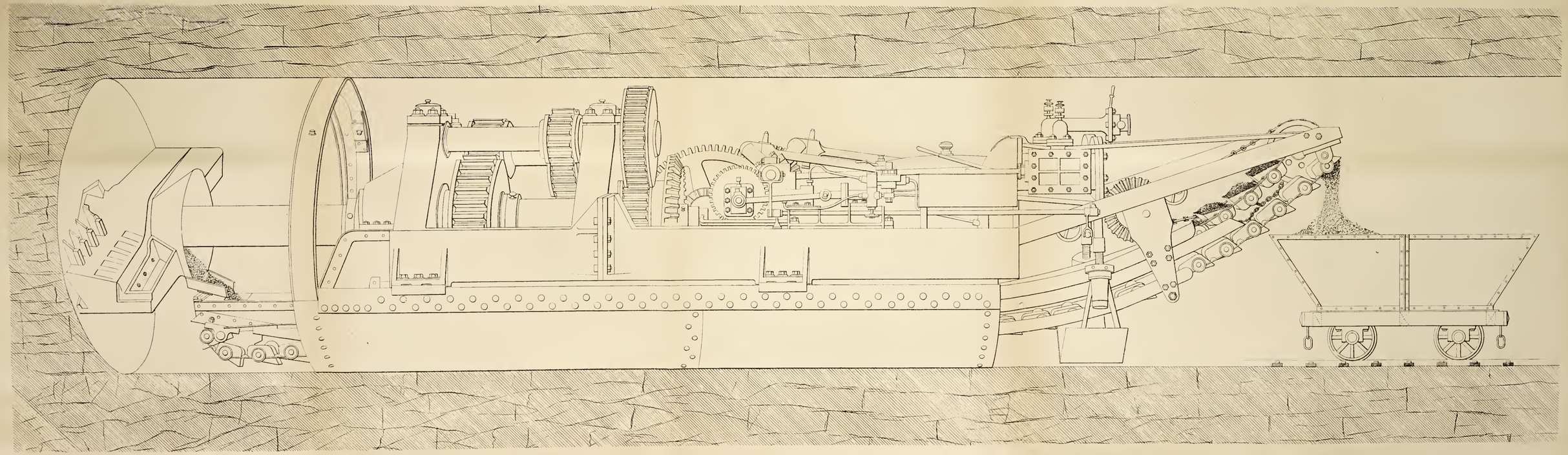

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JOHNSON'S RAILWAY SIGNAL.

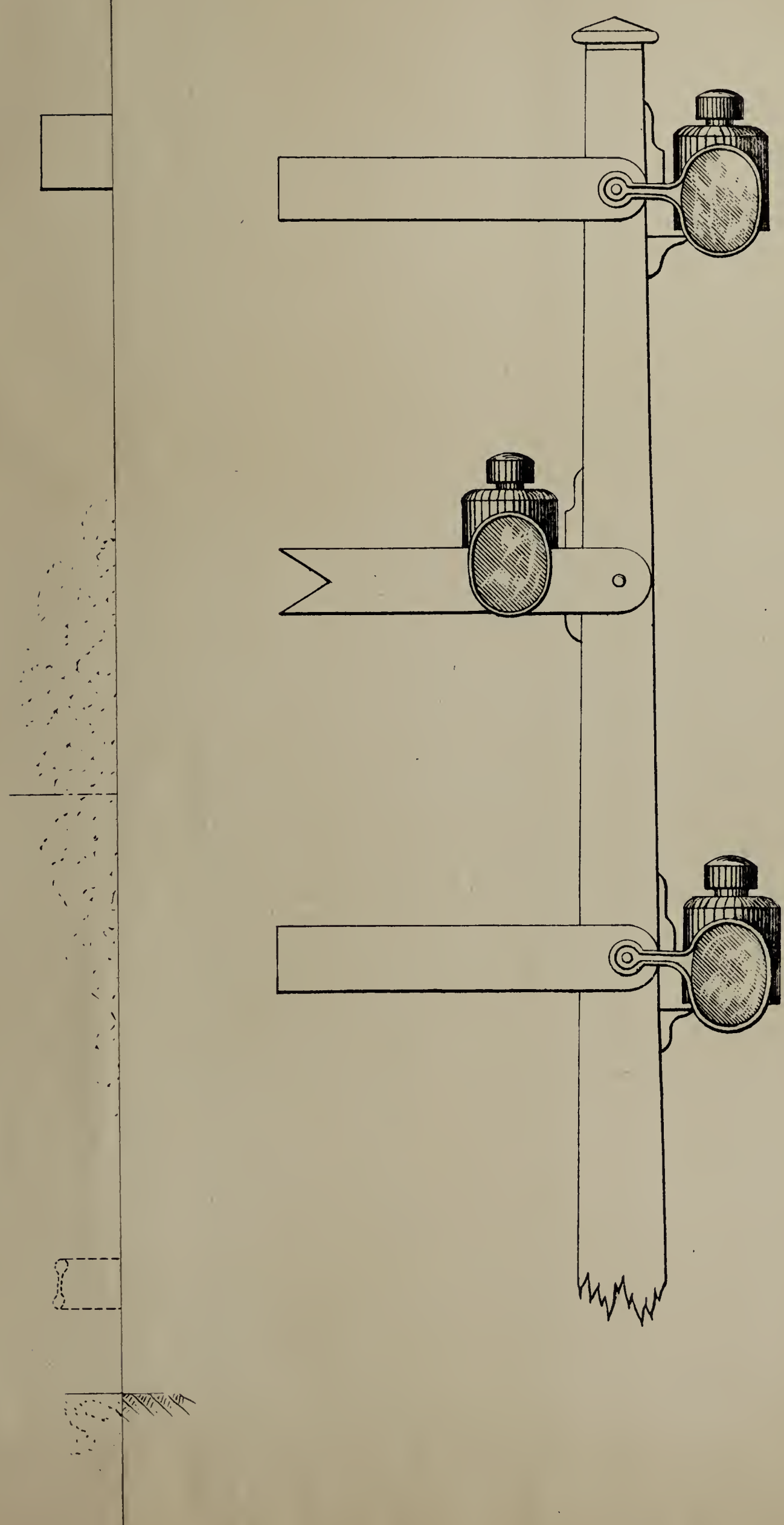


Fig. 2. Section through A B

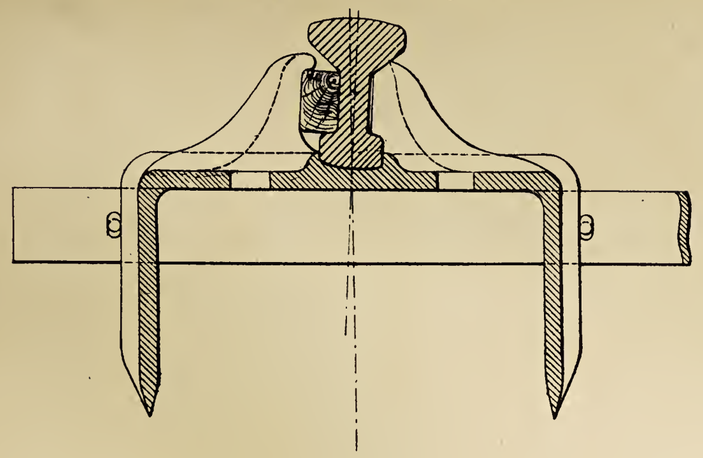


Fig. 3. Section through C D

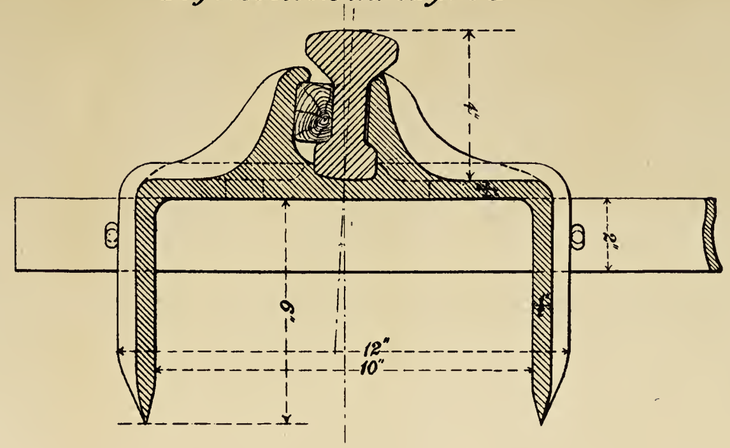


Fig. 1. Plan.

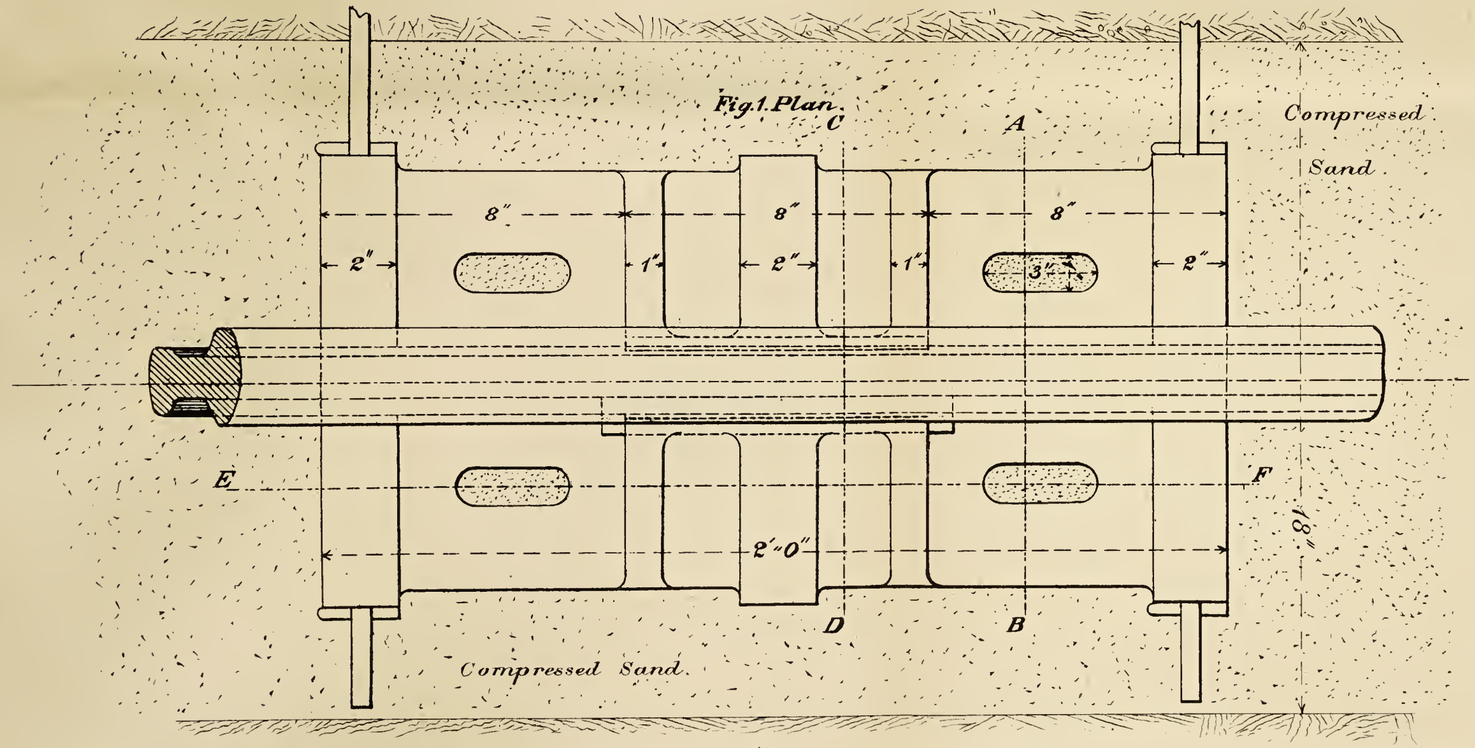


Fig. 4. Section through E F

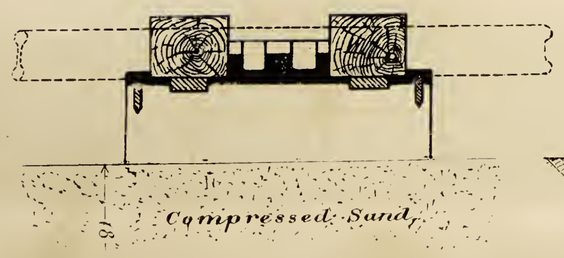
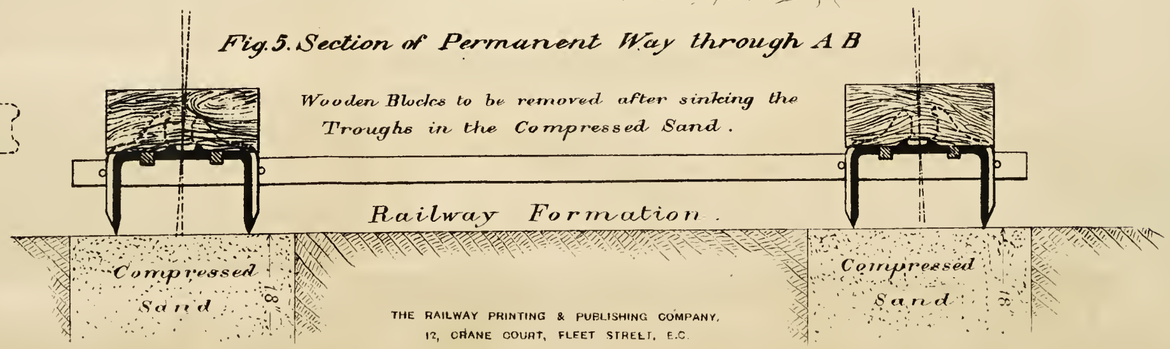
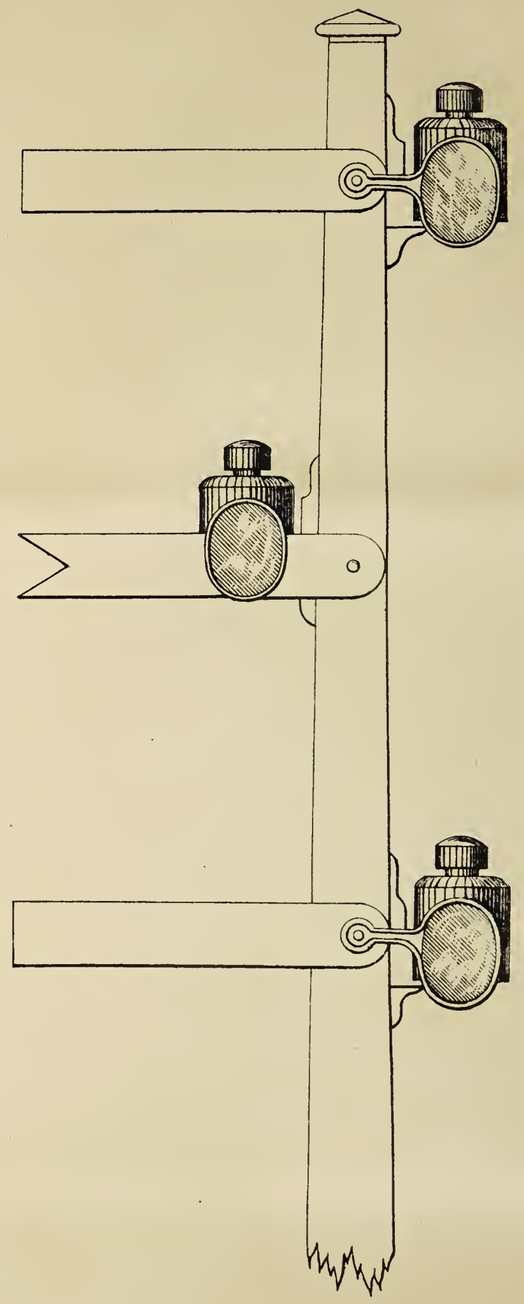


Fig. 5. Section of Permanent Way through A B



JOHNSON'S RAILWAY SIGNAL.



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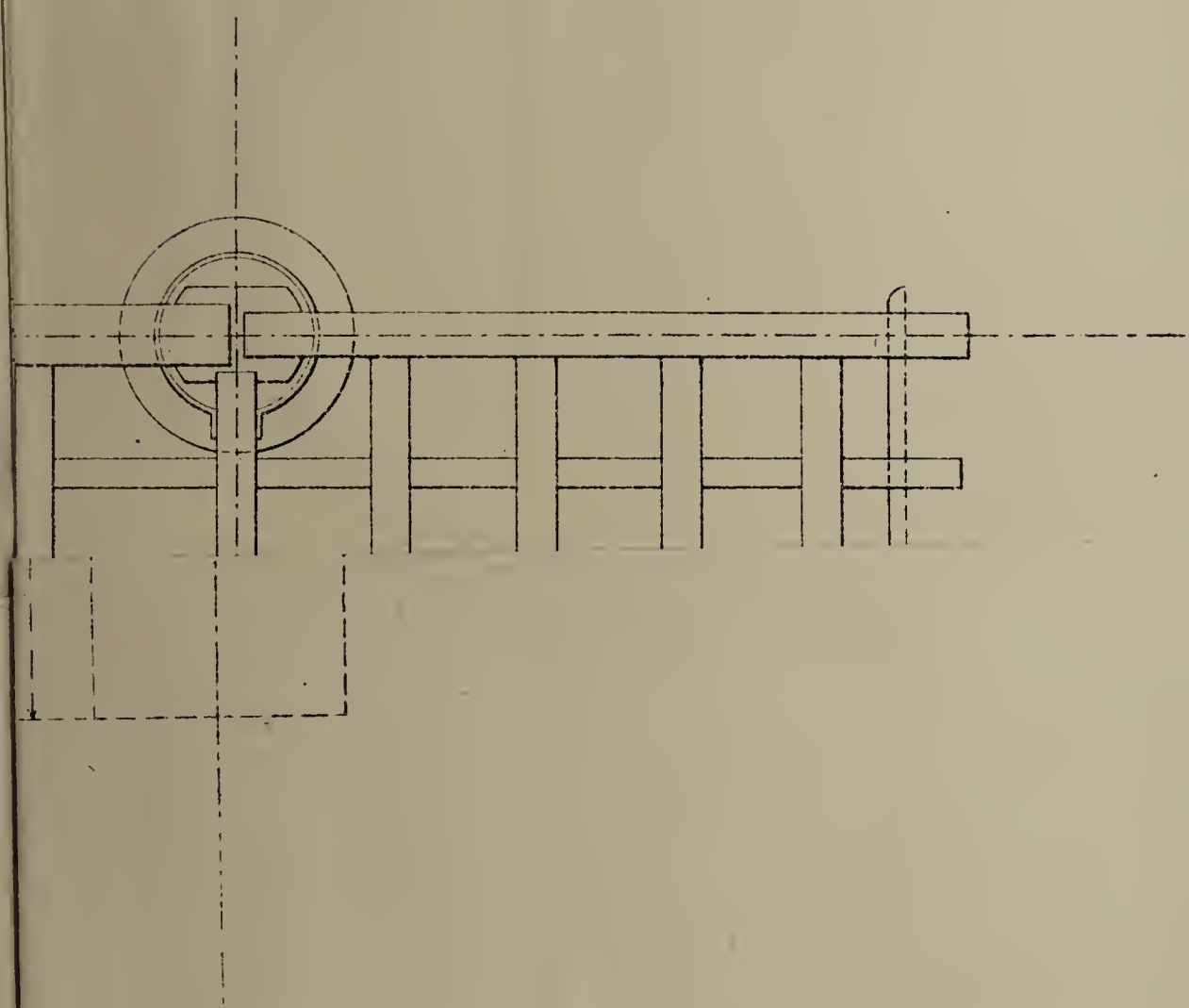
12, CRANE COURT, FLEET STREET, E.C.

PLATE CLXXIII.



BRIDGE OVER THE TEES AT STOCKTON FOR THE NORTH EASTERN RAILWAY.

Engineer Mr Wm Cudworth, Mem. Inst. C.E. Contractor: Mr Walter Scott.
Sub-Contractors for W.I. Girders: Messrs. Wilson Bros. & Co.

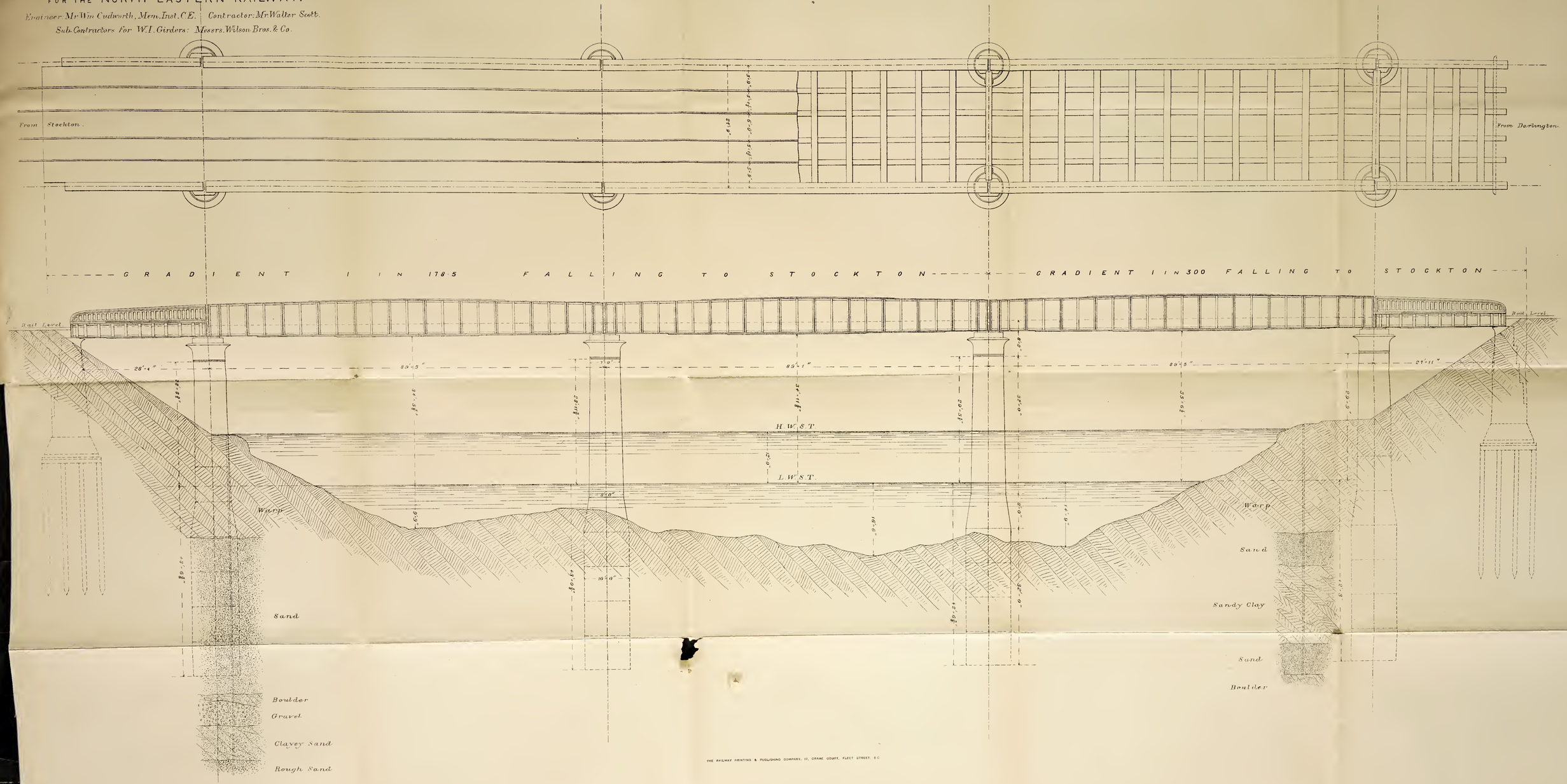


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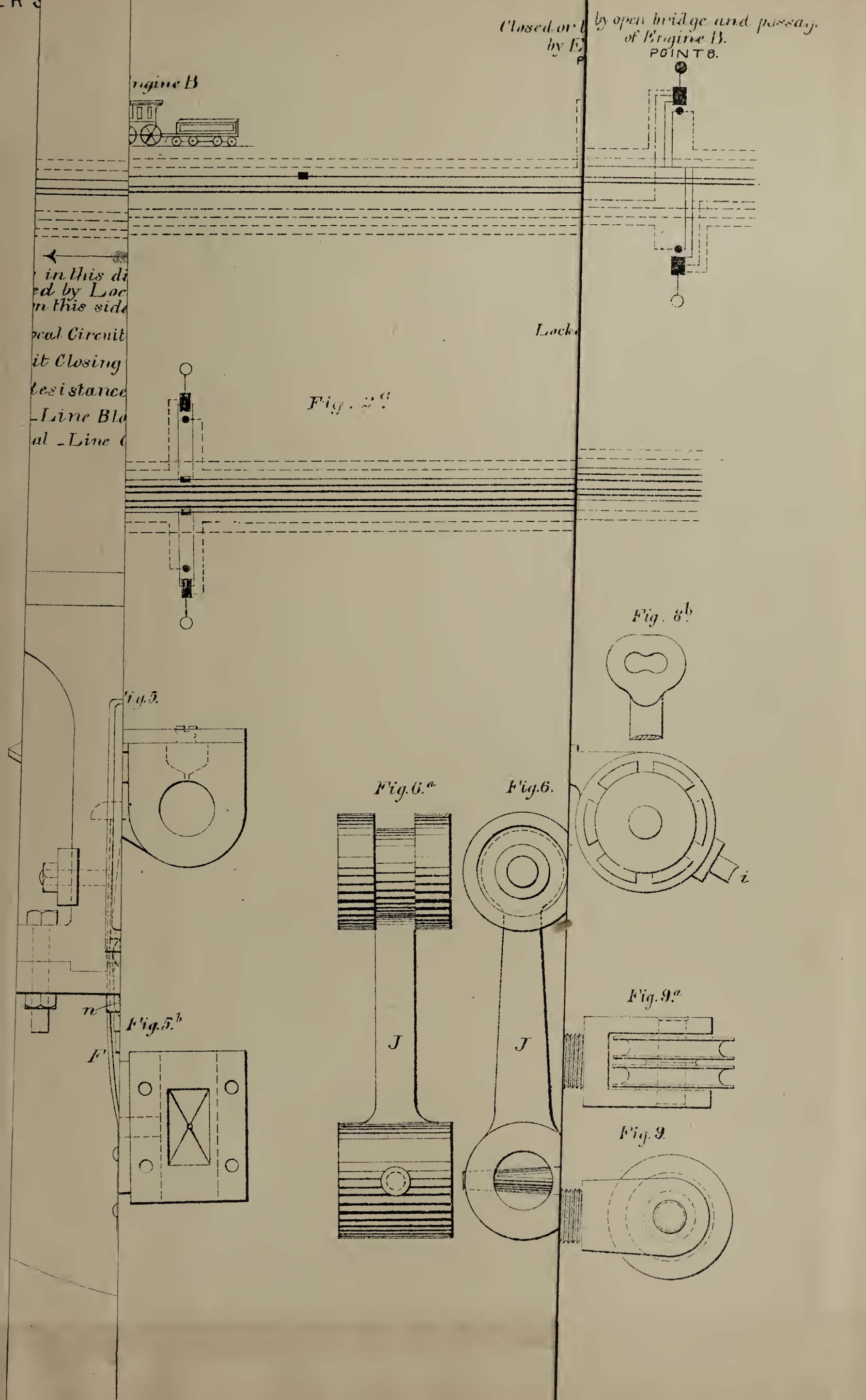
PLATE CLXXIV



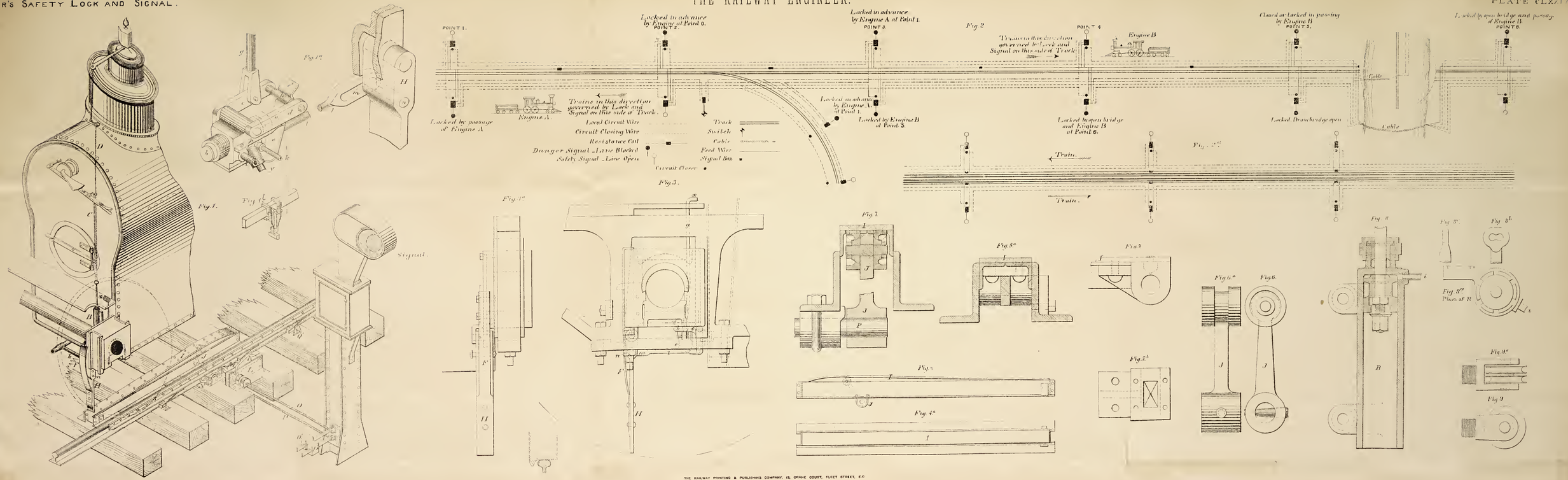


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Fig. 2.

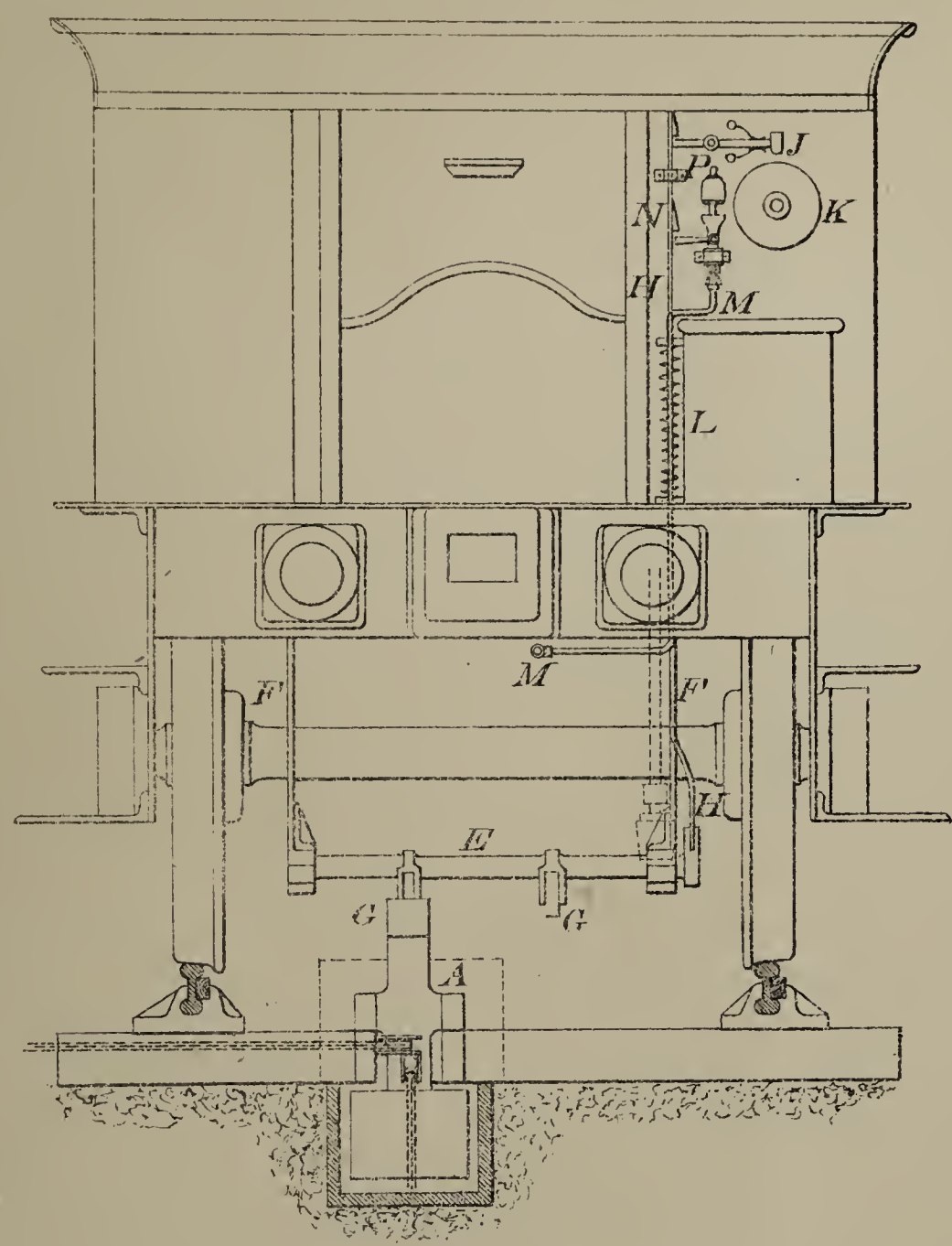


Fig. 3.

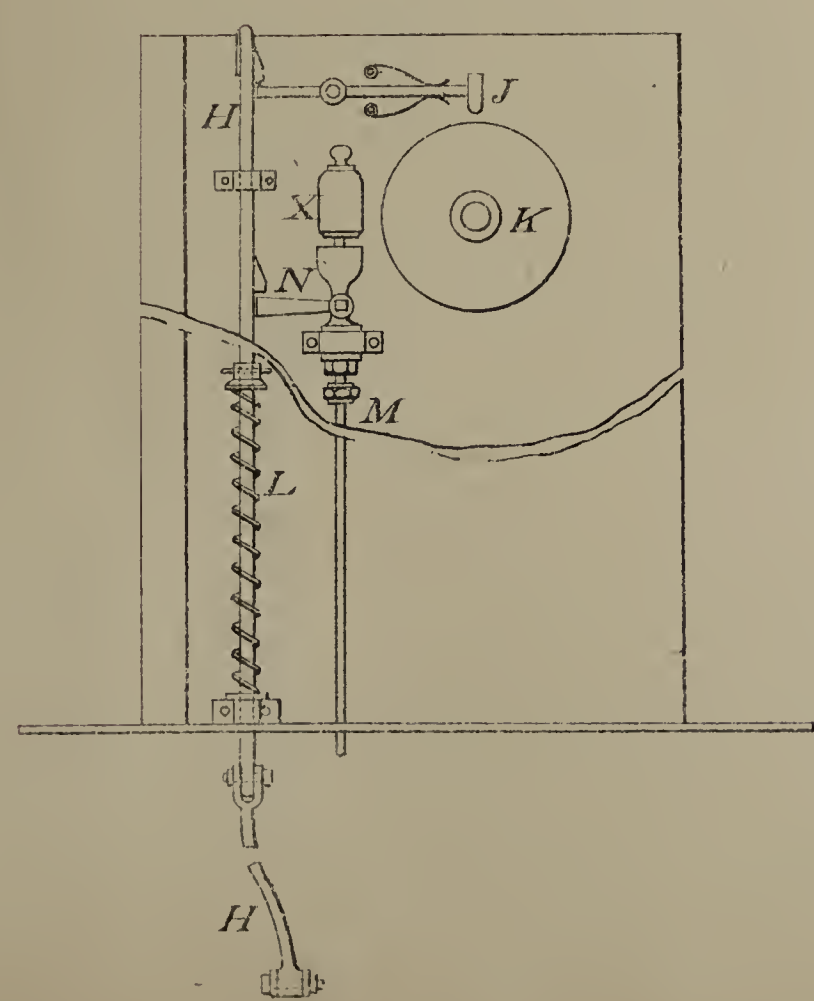


Fig. 1

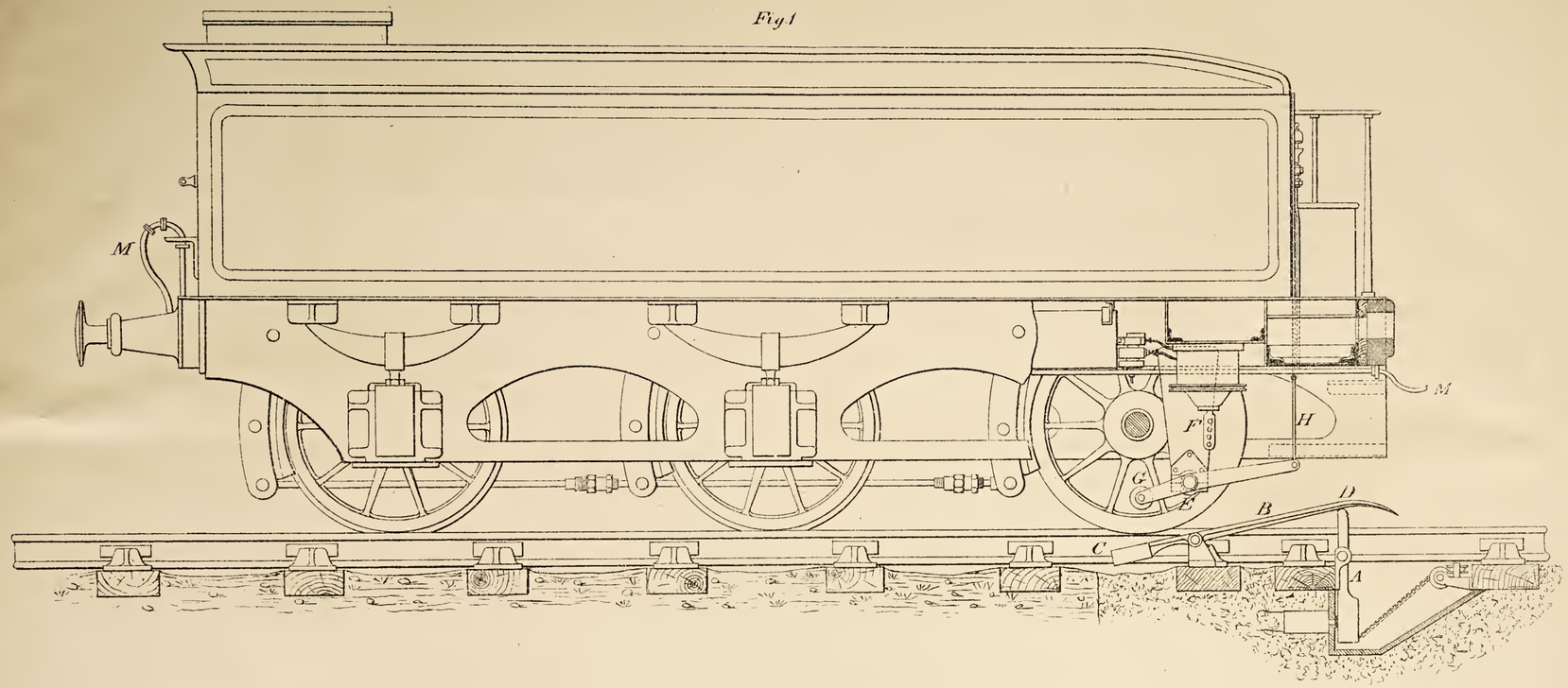


Fig. 2.

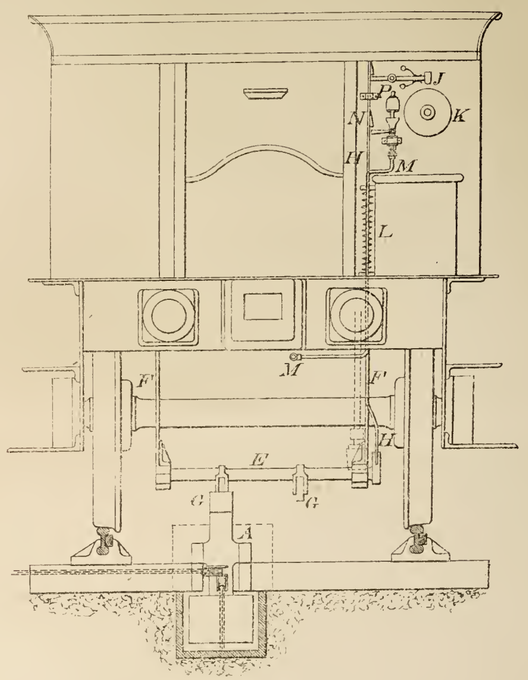


Fig. 4.

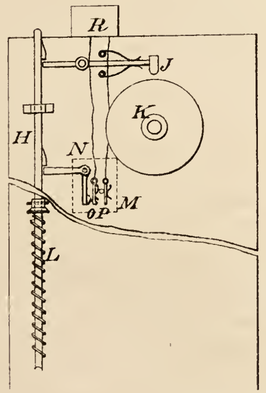
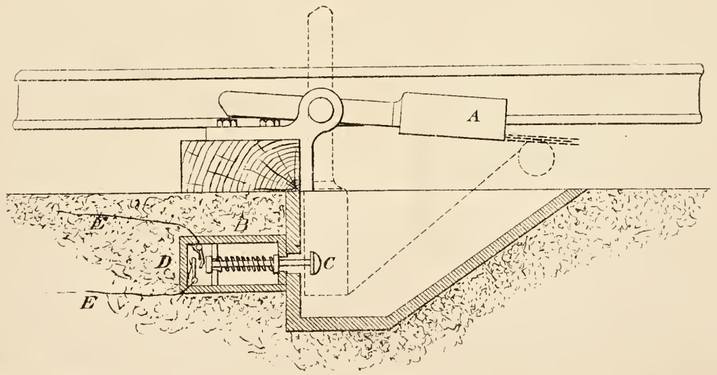


Fig. 5.



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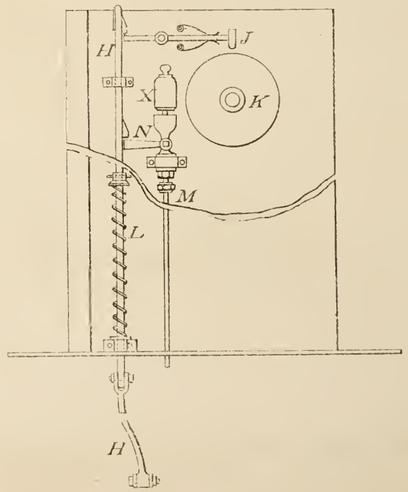

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